Morphological Effects in Visual Word Processing: Their Timecourse and Consequences for Lexical Architecture

Jennifer J. Vannest

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MORPHOLOGICAL EFFECTS IN VISUAL WORD PROCESSING: THEIR TIMECOURSE AND CONSEQUENCES FOR LEXICAL ARCHITECTURE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
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School of The Ohio State University

By

Jennifer Jean Vannest, M. A.

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Dissertation Committee:
Professor Keith Johnson, Adviser
Professor Neal Johnson
Professor Shari Speer

Approved by

Adviser
Linguistics Graduate Program

ABSTRACT

Dual-route models of morphological processing, such as the Morphological Race Model of Schreuder & Baayen (1995) or the Augmented Addressed Morphology Model of Caramazza et al (1988) suggest that language users access many types of affixed words from the mental lexicon either as whole-word units or morpheme-by morpheme. Certain linguistic factors determine whether a given affixed word is better processed by one route or the other: for example, suffixes that are phonologically neutral, share the same form with freestanding words, or are inflections rather than derivations may be more likely to trigger morpheme-by-morpheme "decompositional" processing. This suggests that for different affixes, there also may be differences in the timecourse of whole-word and morpheme-based processing.

The existing models and the experiments used to test their predictions (mainly lexical decision experiments), however, have been generally unable to make claims about this timecourse. In order to address this issue, we examined some English derivational suffixes and an inflectional suffix in four experiments by modifying a standard visual lexical decision or naming experiment manipulating base (root word) and surface (whole-word) frequency, where base frequency effects are assumed to reflect decompositional processing. This setup was combined with a Speed-Accuracy Tradeoff design: participants learned to make lexical decisions or name words after a delay of 150-700 ms. At the end of the delay, a response cue was given, and participants were trained to respond within 300 ms after the signal and were given feedback on each trial regarding their speed. Frequency effects on response times and error rates showed a somewhat different pattern in these results than in the traditional completely subject-paced design: in general, both the base and surface frequency effects that were found (variably across the different suffixes) appeared when response delays were short and disappeared when delays were longer. The combination of effects has interesting implications for dual-route models of morphological processing, and here we propose the Dual-Route Decay model, a more refined version of the existing models that takes into account the timecourse of accessing complex words from the mental lexicon.

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VITA

September 6, 1976..................	born, Wheeling, WV
1996.....................................	B.A. Spanish, The Ohio State University
1998.....................................	M..A. Linguistics, The Ohio State University
1996-present..........................	Graduate Research and Teaching Associate, The Ohio State University

PUBLICATIONS

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CHAPTER 1

INTRODUCTION

1.1 Central questions about morphology in word recognition

The goal of this research will be to refine theoretical models of the role of morphology in the processing of visually presented complex words. When readers process a visually presented complex word, do they access this word from the mental lexicon as one whole word or as a collection of separable morphemes? How would morphological structure have to be represented in the lexicon to affect lexical access? Does morphological structure have a greater effect on the processing of certain types of complex words? And when in the timecourse of comprehending a word does morphological structure have an effect?

In experimental work across languages, effects of morphological structure on the reading of words have been detected with varying degrees of success. Existing models of this process, therefore, suggest a dual-route mechanism where sometimes, affixed words are accessed from the lexicon as single units, and in other cases are broken down, or "decomposed" into component morphemes. While these models can account for a wide range of empirical data, mainly from the lexical decision task, in many cases they are too vague or too flexible to make constrained predictions about behavior in further experiments using a wider variety of complex words.

I propose a more highly-specified version of a dual-route model of morphological processing based on a series of experiments. The experiments herein examine suffixed words in English and will be focused on two issues: the timecourse of morphological processing, and secondarily, differences in experimental paradigms used to examine lexical access.

Overall, further empirical data regarding the timecourse of morphological effects and also how they manifest in paradigms other than lexical decision, can help to generate more a more explicit theoretical model of how morphology fits into lexical processing.

1.2 Organization of the dissertation

Chapters 1 and 2 offer some background on previous experimental work and proposed models of the role of morphology in the reading of words. This previous experimental work involves many lexical decision studies and a few other experimental paradigms, and the theoretical models based on this work have most recently concentrated on varieties of dual-route models. Chapter 3 begins the examination of the timecourse of morphological processing, specifically, how it may help to discriminate between and refine existing models. Also, here I introduce a new methodology for examining the timecourse of lexical access: Speeded Lexical Decision.

Chapters 4, 5, and 6 present original experimental work, first using Speeded Lexical Decision to study derivationally suffixed words, then inflected words. Finally, the speeded task is modified with use of a naming response instead of lexical decision, revisiting derivationally suffixed words.

In Chapter 7, I discuss some issues that are involved in the use of speeded tasks like the ones in the present series of studies. Finally, in Chapter 8 there is a summary of the results and discussion of their implications and questions they raise for future work.

1.3 Previous work on Morphological Processing

Psycholinguistic studies have investigated not only whether or not a morphological decomposition process takes place, but also the details of this process, and a few different methodological approaches have been taken in these studies.

1.3.1 Lexical Decision Experiments

The overwhelmingly most commonly used methodology in these investigations is the lexical decision task. This consists of presentation of a string of letters to participants who must, as quickly as possible make a YES or NO response regarding whether or not the item presented was a word of their language, and their response latency is measured. Taft and Forster (1975) pioneered the use of this task to give evidence for their Affix-

Stripping model, one of the first formally developed theories of how morphologically complex words are processed. They suggested that affixes are decomposed from their roots and then the mental lexicon is searched first for the root only, according to the frequency of the root. In their lexical decision experiments, Taft and Forster (1975) first concentrated on the reaction times of negative responses to English bound roots (such as *cursion* as in *recursion* and *excursion*) and pseudo-stems (such as the *pertoire* in *repertoire*). They hypothesized that if roots were stored separately from affixes in the lexicon, all real roots could be found in the lexicon. Therefore, they suggested that real bound roots would take longer to reject as being words of the language, since their lexical entries can actually be located. People could not make a NO response to these, they explained, until checking the accompanying affixes. In contrast, the pseudo-stems would be faster to reject as words because they could not be found in the set of possible roots in the lexicon. Taft and Forster's lexical decision times indeed showed the consistent pattern: real roots took longer to reject than pseudo-stems.

The second experiment that Taft and Forster (1975) presented in support of their Affix-Stripping model examined real bound roots in English that can also stand alone (with different meaning) as individual words: for example *vent,* which Taft and Forster hypothesized had two separate lexical entries, one for the bound morpheme (as in *prevent*) and one for the separate word. If this is the case, and roots are indeed separable units, Taft and Forster predicted that these bound morphemes, when they are more frequent than their whole-word counterpart, would interfere with access of the whole-word and slow down lexical decision times. In cases where the whole-word form is more

frequent, lexical decision latencies would be shorter. They found this pattern of response times in their experiments, which they credit as further support for the Affix-Stripping model where roots and suffixes are separable.

The results of Taft and Forster (1975) led to several further uses of the visual lexical decision task into the role of morphology in lexical access. One of the most robust properties of the lexical decision task is that it is highly sensitive to word frequency (Broadbent, 1967 cited in Taft, 1979): more frequent words elicit quicker responses. This property has been exploited in investigations of morphological processing. Taft (1979) compared prefixed derived words with high base frequency (the sum of the frequencies of all the words with that root) with other prefixed words with low base frequency. These words were matched for surface frequency (the frequency of each prefixed whole-word itself), and Taft suggested that if the morphemes in the prefixed words were being accessed separately, base frequency would have an effect on response times. Indeed, those prefixed words with high base frequency were responded to more quickly in lexical decision than those with low base frequency, offering further support for the Affix-Stripping type of model that involves a morphological decomposition process. Taft (1979) also followed up this experiment with a similar design involving English words with inflectional suffixes: and again, base frequency influenced response time, suggesting that this process can take place in both prefixed and suffixed words.

Bradley (1980) used a very similar frequency-contrast design to that of Taft (1979), but refined the choice of stimuli to look at specific derivational suffixes in English, whereas Taft (1979) had examined a variety of derivational prefixes and inflectional suffixes. Bradley (1980) collected lexical decision times for words with

–ness, *–er*, *–ment*, and *–ion*, and for each, she used: first, sets of high base frequency and low base frequency words matched for surface frequency; and second, sets of high surface frequency and low surface frequency words matched for base frequency. She found that for sets of words with the first three suffixes, the contrasts in surface frequency and base frequency affected response time, but for *–ion* words only the surface frequency contrast had an effect. This suggests that a morphological decomposition process took place for the *–ness –er*, and *-ment* words only. Bradley, then, uses this pattern of results to make hypotheses about the structure of the mental lexicon: she suggests that there is a difference in the way certain types of suffixes are stored. Neutral suffixes, she explained, (those that cannot make phonological changes to the words they attach to) are separate from their corresponding roots, but words with non-neutral suffixes are stored as whole units.

Around this time, visual lexical decision was also used to investigate morphological processing in languages other than English. Lukatela, Gligorijevic, Kostic, and Turvey (1980) collected lexical decision times to inflected nouns in Serbo-Croatian, which has a much more complex system of case suffixes than in English. They found that reaction times to nominative singular nouns were faster than those to nouns with genitive or instrumental case markers. Lukatela et al suggested, from this, a decompositional-type lexical access process where non-nominative-singular suffixed words receive activation and are recognized via activation of the nominative singular

base form. Specifically, they hypothesized that the lexicon is not structured with separate base words and affixes but that suffixed forms create clusters around the central nominative singular and their access is mediated by it.

A more detailed model of the processing of inflectional suffixes, also examining a language with a richer morphological system than English, was presented more recently by Caramazza, Laudanna, and Romani (1988). They collected lexical decision data on Italian inflected verbs, concentrating on nonwords designed similarly to those in Taft and Forster (1975). They found that real word roots with inappropriate (real) inflections took longer to reject as words than either real roots with nonsense suffixes or nonsense roots with real suffixes; and non-decomposable nonwords were even faster to elicit a NO response. According to the Affix-Stripping model, real roots with nonsense suffixes would be equal to non-decomposable nonwords because neither of them have real suffixes that can be initially decomposed, but this is not the pattern of Caramazza et al's results. They accounted for this by presenting their Augmented Addressed Morphology (AAM) model, a compromise between a decompositional model and whole-word access. They argued that morphological decomposition is optional, and suggest a dual-route process where known words are accessed via whole-word forms, and a decomposition strategy is only necessary with unfamiliar words (when the whole-word access process fails but real morphemes are present). They hypothesized that this would be the case with derived words as well.

Since the development of dual-route models such as the AAM, many investigations have focused on the question of under what conditions a decomposition route would be used; specifically, what properties of the words like those investigated by

Taft (1979) or Bradley (1980) caused them to display decomposition effects? While Caramazza et al (1988) assumed that morphological decomposition is completely optional except in the case of unfamiliar words, other researchers have found these results suspect, particularly because they are based on responses to nonwords. This has led others to hypothesize that decomposition is mandatory or at least highly likely, in certain cases.

Marslen-Wilson, Tyler, Waksler and Older (1994) combined the lexical decision task with a cross-modal priming paradigm in order to investigate what factors might induce decomposition effects in derived words. They collected lexical decision times to visually presented words that appeared immediately after auditorily presented primes. They found that base morphemes (they chose those that could stand alone as individual words) primed derived words, and vice versa: suggesting that the words were indeed being accessed via their component morphemes. For example *friendly* and *friend* primed each other, and Marslen-Wilson et al took this as evidence that the root was being accessed in the processing of the affixed form. Importantly, however, these results were only true of words where the relationship between the root and affixed word was semantically transparent (as in *friend/friendly* versus *author/authority*). In other words, Marslen-Wilson et al suggested that separate access of roots and affixes only takes place

in the most transparent cases[1]. They also found that derived words with different affixes did not prime each other: suggesting a model similar to that described by Lukatela et al where affixed forms are accessed via a central common root.

Schreuder and Baayen (1995), like Marslen-Wilson et al (1994), suggested that morphological decomposition is indeed used in normal access, and they present this in the framework of a dual-route access model similar to Caramazza et al's AAM model. They proposed that decomposition and whole-word access routes operate in parallel, and the quickest route is the one that is used (except for semantically transparent but low frequency inflected forms which are always decomposed)[2]. This model is termed the Morphological Race Model (MRM), and Schreuder and Baayen (1995) discussed previous lexical decision results in its context. The MRM predicts that while whole-word access of morphologically complex words is almost always possible (and is affected by frequency), a variety of factors may make a decomposition process more efficient. These include base and surface frequency, productivity, semantic transparency (as in Marslen-Wilson et al's 1994 results), and perhaps others.

Niemi, Laine and Tuominen (1994) also found evidence for a morphological decomposition process in visual lexical decision using a language with an extremely rich morphological system: Finnish. They found that case-inflected nouns elicited longer lexical decision times than monomorphemic words matched for frequency; they interpreted this as evidence for an extra processing step in the case of the suffixed words. They found this effect even in cases where there were morphophonological (and

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[1] Wurm (1997) also stressed the importance of semantic transparency when he found decomposition effects in auditory lexical decision. He also collected norms where people rated how "prefixed" a word seems. Higher "prefixedness" also made decomposition effects more likely.

[2] The details of the MRM's architecture will be discussed in chapter 2 below.

corresponding spelling) changes in the root morphemes. They suggest a model where affix-stripping takes place for inflections and not derivations: this is not inconsistent with a dual-route model such as the MRM, where status of an affix as an inflection (which would also be high in productivity) might make the decomposition route more efficient or even mandatory.

More lexical decision experiments, this time in Dutch, by Baayen, Dijkstra and Schreuder (1997) were used to further develop the MRM. They used a frequency-contrast (similar to Taft, 1979) design examining nouns and verbs with plural suffixes and found that in some cases, decomposition effects did not arise for plural nouns. They attribute this, in the context of the MRM, to the ambiguity of one of the plural suffixes, -*en*, which is predominately used as a verbal suffix. This ambiguity (also referred to as affixal homonymy), they explain, is one reason that makes the decomposition route longer takes than whole-word access for these nouns. This is not the case for verbs, where the *–en* suffix is used more frequently and is not ambiguous: decomposition effects arose in these cases. They also suggest that some of the plurals were very frequent as whole words (had very high surface frequency) and could therefore be accessed via the whole-word route quite quickly, leading to a lack of decomposition effects in lexical decision.

Alegre and Gordon (1999a) used lexical decision evidence to make a further case for whole-word access of frequent surface forms. They collected response times to a large number of regularly inflected words in English across a wide range of surface frequencies (matched for base frequency in each group). They found a correlation between response time and surface frequency only for words over 6 per million in surface

frequency: a result consistent with both the AAM and MRM dual route models. In the AAM, decomposition (rather than whole-word access) is only used in the case of unfamiliar words. These same words in the context of the MRM might be accessed faster via decomposition since the whole-word route would be slow in these infrequent cases.

Other recent studies have taken the approach of Bradley (1980), and looked for frequency effects in lexical decision on a suffix-by-suffix basis, in hopes that the properties of these individual suffixes might shed some light on what factors might make decomposition an efficient strategy in the context of a dual-route model like the MRM. Vannest and Boland (1999), for example, found evidence of a decomposition route (base frequency effects in lexical decision) for words with a phonologically neutral, more productive derivational suffix -*less* ("Level 2" suffixes in Kiparsky's (1982) Lexical Morphology), but not for more idiosyncratic structure-changing "Level 1" derivations with the suffixes -*ity* and -*ation*, where the whole-word access route seemed more prevalent. In Finnish, Bertram, Laine, & Karvinen (1999) found for derived words with -*jA* (loosely comparable to -*er* in English) that lexical decision latencies were equal for monomorphemic and derived words. They follow Baayen et al (1997) and claim that words in the -*jA* suffix complicate the decomposition route, due to the fact that the suffix -*jA* is homonymic (it denotes partitive plural as well). Words in the low-productive denominal locative marker -*la* elicit again equal reaction times as their monomorphemic controls, pointing to productivity as a factor. At the same time they found that words with a more productive derivational suffix, -*stO* elicit shorter response latencies than their monomorphemic controls. Bertram et al. (1999) argue that when words with productive, unambiguous suffixes are processed via the whole-word route and the decomposition route simultaneously, average reaction times on *-stO* words may actually be boosted.

In a direct comparison with the Finnish study of Bertram et al. (1999), Bertram, Schreuder, and Baayen (2000) used the Bradley (1980) frequency-contrast design in lexical decision to examine several suffixes in Dutch. They suggest a similar kind of interplay between suffix type, affixal homonymy, and productivity. With respect to derivations, they find whole-word effects only for words in unproductive and ambiguous affixes, but both whole-word and base frequency effects for complex words with a productive, unambiguous derivational suffix. However, Bertram et al. (2000) find no decomposition effect for the productive Dutch deverbal subject marker *-er* which is homonymic in that it also denotes the comparative marker (parallel to English *–er*). Consistent with earlier results, the authors argue that due to affixal homonymy, the decomposition route is hindered to an extent that processing effectively takes place via full forms only. In general, these studies support models like the MRM where the variable use of decomposition and whole-word processing can, in part be explained by taking into account properties of individual affixes.

In further cross-linguistic studies using the Bradley (1980) design, Vannest, Bertram, Jarvikivi and Niemi (submitted) find both base and surface frequency effects for English derivationally suffixed words with *–ship*, *–hood* *–able* and *–ness*, suggesting use of decomposition. For derivationally suffixed words in Finnish with *-kAs*, *-tOn* and *–isA*, however, they found no base frequency effects, suggesting whole-word access. They argue that the prevalence of suffixation in Finnish, which has a very rich morphological system, actually makes use of whole-word processing of derived words advantageous, since these derived words usually appear with one or more inflections at the end of the word. Such a strategy combining whole-word access and decomposition would make it possible for the Finnish language user to avoid double and triple levels of computation that would otherwise occur frequently. In English, they explain, this extra computation would be rare, so derivational suffixes can be handled, in many cases, with a decomposition process. They concur with earlier findings as well, in suggesting that factors like semantic transparency productivity or, homonymy may affect the likelihood of using morphological decomposition processes cross-linguistically, and then that language specific differences may indeed result from the exposure of language users to different morphological structures.

1.3.2 Other Experimental Paradigms

While use of lexical decision has dominated work on morphological processing, a few other methodologies have been used in recent investigations. Rueckl, Mikolinski, Raveh, Miner and Mars (1997) used a long-term priming paradigm in which the task was not lexical decision, but fragment completion. First, they gave participants a study task where they gave familiarity ratings to words that included some English suffixed primes with a variety of suffixes. After that, they presented target words that were the roots of the suffixed primes, with letters either missing or masked. Participants responded, as quickly as possible, with the missing letters. Each target had multiple possible completions: and if the target was completed with the letter that actually made up the root of primes the participant had seen in the study task, Rueckl et al (1997) interpreted this as evidence for morphological priming. They found that suffixed words always primed their roots, reliably better than controls with the same degree of matching orthography. These results suggest a decomposition process, which Rueckl et al capture as connections between roots and suffixes in a connectionist network.

Rueckl et al (1997) made no distinctions among the suffixes or types of suffixes that they used in their experiments. More recently, however, Raveh and Rueckl (2000) used the priming/fragment completion design again. They separated inflections and derivations in English and found an equal amount of priming for both. Within these groups, they did not analyze individual suffixes separately as in many lexical decision experiments, but used fairly productive suffixes in words with high surface frequency. They explain that their results can be interpreted in the context of a connectionist or a dual-route model, though their model could be made much more detailed with an analysis of individual suffixes, where priming effects may have varied.

Another source of information about the role of morphology in lexical processing comes from the language performance of brain-damaged patients. Badecker and Caramazza (1991), for example, present some single-word reading data from a patient with mild left-hemisphere damage whose main deficiencies appeared in reading and writing individual words. Specifically in Badecker and Caramazza's (1991) experiments, this patient made much more frequent errors in reading morphologically complex words (inflections and derivations) and would often substitute one affix for another when asked to read affixed words aloud. They suggest that this patient's normal processing must have included a system for decomposing morphologically complex words, or at the very least, a composition system for their production, that was failing in this patient's

performance. Similarly, Niemi et al (1994) describe two dyslexic patients who have great difficulty in reading inflected words in Finnish (though they perform better on derivations) suggesting decompositional processing of Finnish inflections, consistent with studies of normal processing. Examining Japanese-speaking aphasic patients, Ito, Sugioka, and Hagiwara (1996) found that Broca's aphasics had difficulty with producing a regular derivational suffix, but not more irregular forms: they found the opposite pattern for Wernicke's and Transcortical aphasics. This suggested a dissociation between regular and irregular suffixation that might be due to a decomposition process for the former.

Eyetracking, a paradigm usually reserved for investigating visual stimuli larger than single words, has also recently been used to investigate morphological processing. Hyona, Laine & Niemi (1995), for example, found that participants fixated as long on monomorphemic control words as on derived words matched for frequency, while performing a lexical decision task in Finnish. This confirmed lexical decision evidence from other studies that while Finnish inflected words seem to processed via decomposition, derivations are not. Bertram, Hyona, and Laine (submitted) found a similar pattern of results in eye fixation times for morphologically complex words presented in sentence contexts.

So while lexical decision experiments clearly dominate work on the role of morphology in lexical processing, a few other paradigms have been used more recently. These help to confirm that at least under some conditions, words are processed by being broken up into their component morphemes. Factors like productivity, semantic transparency, affix type (inflection/derivation, phonologically neutral/non-neutral), homonymy, base and surface frequency and cross-linguistic differences all appear to play a role: but their interaction is not well understood at this point. Dual-route models like the Morphological Race Model are flexible enough to accommodate the influence of all such factors and therefore can account for the existing data. However, the timecourse of the influence of this linguistic and frequency information has not been investigated, and the models are not detailed enough to make constrained predictions about future results: as discussed in Chapter 2 below. Hopefully through additional data the models' architecture can be better nailed down.

This dissertation presents data from speeded lexical decision and speeded naming experiments designed to explore some of the factors involved in processing morphologically complex words.

CHAPTER 2

EXISTING MODELS OF MORPHOLOGICAL PROCESSING

2.1. Early Models

Traditionally, models of morphological processing basically took two possible approaches: either that words were processed as whole units and accessed from the lexicon as such, or that they had to be broken down into component morphemes in order to be processed. The most frequently cited model that assumes full lexical listing and access of all morphologically complex words is the Full-Listing Hypothesis of Butterworth (1983), who suggested that all prefixed and suffixed words had individual lexical entries without regard to internal morphological structure. Such a model may seem elegant because of the lack of any need for a morphological parsing process in word comprehension or a composition process in word production. However, effects of morphological structure found in experiments performed even earlier (Taft and Forster 1975, Taft. 1979, Bradley 1980, all detailed in Chapter 1 above) seem to refute the hypothesis that morphological structure does not play a role in the understanding of complex words. In addition, as Hankamer (1989) argues, languages with highly productive agglutinative morphology, such as Turkish, seem like impossible candidates for full lexical listing. In these languages, new words made up of combinations of component morphemes are constantly being generated and used; that a language user would store all the possible combinations of morphemes, even those which he or she has not yet encountered, seems highly unlikely. For these reasons, researchers have made an effort to model how morphological structure is coded in the lexicon and what role it plays in online processing of complex words.

The major early alternative to full listing was the Affix-Stripping model of Taft and Forster (1975). They hypothesized that when words are read (we will concentrate on visual processing for the purpose of this discussion), they are immediately separated into root and affix via comparison with orthographic access representations[3] held in memory. These access representations do not contain any semantic or syntactic information about words, but simply the structure of a particular letter pattern. Then, the lexicon, which contains this more detailed information on a morpheme-by morpheme basis, is searched for the presence of the root morpheme. Assuming the root is indeed a real one in the language, affixes are then checked for combinability with the root: then the word is recognized and further information associated with it can be processed. This model accounted for data collected by Taft and Forster (1975) and Taft (1979) showing morphological decomposition effects.

However, a fully decompositional model such as this has also failed to be well-supported by experimental evidence. Bradley (1980), for example, found base frequency effects in lexical decision for words with some suffixes but not with others; and

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[3] The existence of modality-specific access representations is subject to question, though more so in the auditory modality than visual. See Marslen-Wilson et al (1994) and Marslen-Wilson and Zhou (1999) for discussion.

Caramazza et al's (1988) results also suggest that separate processing of base forms and then affixes may not always apply. Since eventually we are able to recognize morphologically complex words as whole units and also as having separable parts, it seems logical that both kinds of information would be represented lexically. This argument, along with the lack of empirical support for decompositional or whole-word processing has prompted the development of dual-route models, which include both possibilities for lexical access.

2.2. The Augmented Addressed Morphology Model

One such model that is able to account for much of the available data is the Augmented Addressed Morphology model (AAM), developed by Caramazza et al (1988) and others. As in the Affix-Stripping model, words have modality-specific orthographic access representations. However, the AAM uses whole-word access representations, rather than individual morphemes, as default. Morpheme-by-morpheme access representations are indeed present in the model, and are activated alongside whole-word representations, but they are only used for access when no whole-word representation is present: in the case of unfamiliar complex words. These access representations, activated by the perceived letter string, in turn activate a second level of representation: the lexical entries, where more detailed syntactic and semantic information is encoded. In the AAM, these higher-level representations are always fully specified for morphological structure (See Figure 1).

This model accounts for, first of all, the differences in lexical decision times that Caramazza et al find among different kinds of nonwords. Their nonwords made of real morphemes took participants the longest to reject because, Caramazza et al suggest, the lexical access system treated them like unfamiliar words: they had no whole-word access representations, but had, as a backup, morphemic access representations that were activated. These nonwords could not be rejected until the combinability of the morphemes was checked. In the AAM such combinatoric information (i.e. whether the sequence of morphemes is legal in the language) is assumed to be available early – at the level of access representations, but these nonwords still had longer rejection times than those words that did not have access representations available **at all** for one or both of their morphemes.

So while they fail to explicitly explain at what point in the AAM's lexical processing a lexical decision can be made[4], Caramazza et al do seem to base this on activation of access representations, which makes sense, since only real words would have access representations, and nonwords would not. Even those unfamiliar real words

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[4] What exactly constitutes "lexical access" in this model is not explicitly defined either (see 2.4), though the AAM does make some specific claims about what kind of lexical information is available at what representational level.

that are they claim are accessed morpheme-by-morpheme can be accepted at the access representation level, since the combinability information about the morphemes is also available here, early in processing.

The AAM also considers the access representations the locus of frequency effects, and this accounts for more of the lexical decision data. Whole-word (surface) frequency effects, found by Bradley (1980), Baayen et al (1997), Vannest and Boland (1999) Bertram et al (2000) and Vannest et al (submitted) are easily explained by the model by way of the whole-word access representations, which are the default access route for known words in the AAM. Access representations for more frequent words are more easily and quickly activated (they have lower thresholds) than those of less frequent words. In addition, the results of Alegre and Gordon (1999a) are particularly consistent with this model. These authors found a correlation between surface frequency and lexical decision time for words above a frequency threshold of 6 per million. Infrequent words did not show this pattern: these are unfamiliar words that according to the AAM would not have whole-word access representations, but would fall back on morphemic access.

Evidence for decomposition of familiar words, manifested as base frequency effects in lexical decision as were found by Bradley (1980), Vannest and Boland (1999), Bertram et al (2000), Vannest et al (submitted) and others, is not explained as clearly by the AAM. Since access representations are the locus of frequency effects, and whole-word representations are used for access of known words, where might these base effects come from? Caramazza et al hypothesized that they result from long-term priming from the higher lexical level, where representations are decomposed. Specifically, base representations at the lexical level that are activated frequently (on their own or as parts of other words) effectively prime any access representation containing that base form, and make it more sensitive to activation. So according to the AAM, words with highly frequent bases may indeed have faster lexical decision times, but not because they are accessed via their component morphemes. Caramazza et al also consider an alternative account of base frequency effects: that they arise online at the level of lexical entries. This account, however, would require changing the point at which lexical decision responses can be made to later at the lexical level: so the authors favor the priming account.

Long-term priming data, such as that presented in Rueckl et al (1997) and Raveh and Rueckl (2000) can also be handled by the AAM[5]. In their task, fragment completion, the lexical items that participants read in the training task influence the letter choices that they make. This effect could take place at the level of lexical entries, which would be called upon when the participant makes a letter choice that forms a real word. Entries that are more highly activated due to priming would be more likely to influence the choice. And since this level of representation includes full morphological structure, priming of bases by suffixed words, a decomposition effect, seems likely.

Returning to the data from lexical decision, however, there are some patterns that the AAM does not seem to cover well. For example, Niemi et al (1994) found that case-inflected words elicit longer response times than monomorphemic controls. Since all real words are accessed via whole-word representations in the AAM, and the lexical decision task can be performed at the level of access representations, this model would predict the response latencies to simple and complex words to be the same if frequency is matched (unless frequency is very low and the complex words had to be accessed morpheme-by-morpheme): not the pattern of results found by Niemi et al.

Also, the AAM explains base frequency effects in lexical decision as long-term priming from the base form at the higher lexical level. Affixed words with high-frequency bases, then, are more easily activated than those with less frequent bases. This implies that base frequency effects should then occur for all affixed words, and the experimental evidence does not bear this out. Bradley (1980), Vannest and Boland (1999), Bertram et al (2000) and Vannest et al (submitted) all found cases, across languages, of derived words that did not show base frequency effects. Perhaps the AAM could be adapted so that these affixed words are treated more like monomorphemics, and their morphological structure would not be represented in the same way as that of affixed words that do show base frequency effects. Even if this change was made, the AAM does not account for some generalizations among the suffixed words that do and do not show frequency effects. Specifically, base frequency effects found by Bradley (1980), Vannest and Boland (1999), Bertram et al (2000) and Vannest et al (submitted) were found for derived words with phonologically neutral, fairly productive, unambiguous suffixes, with some cross-linguistic differences. These properties, which seem to motivate processing differences, are not taken into account in the AAM model.

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[5] Rueckl and colleagues explain how a connectionist architecture can implement their data, though they do not consider this a necessary alternative to a dual-route symbolic model, which also accounts for the data. The differences between the possible implementations will not be addressed here.

2.3. The Morphological Race Model

These generalizations seem better accounted for by the other major dual-route model that has been proposed: the Morphological Race Model (MRM) detailed by Schreuder and Baayen (1995) and Baayen et al (1997). In the MRM there are actually three levels of representation: modality-specific (orthographic) access representations similar to those in the AAM; a second level of lemmas, or modality-independent lexical entries; and a third level of corresponding syntactic and semantic information. The access representations, like in the AAM, are activated by the perceived letter string. The MRM assumes that there are access representations for all individual morphemes and most familiar whole word forms (details below), and that these are the locus of frequency effects, as in the AAM. Each whole word and morpheme also has a lemma representation that is activated by the access representations (See Figure 2).

For whole-word access, Baayen et al (1997) explain, the time it takes for both levels to be activated[6] is completely dependent upon the surface frequency of the form. For morpheme-by-morpheme access, the time it takes to activate the representations at both levels is also dependent on frequency, this time of the base morpheme. Then, before a lexical decision can be made based on the decomposition route, the morphemes must be checked for combinability and, according to the MRM, "re-composed", so that activation may pass on to the associated syntactic and semantic features. (Baayen et al (1997) call the additional time expended for this process "parse time"). Both whole-word and decompositional access **almost always** proceed simultaneously in the MRM, and the one that proceeds fastest is the one that is used and is the one that affects lexical decision latencies. The whole-word route seems by default faster, since it does not include any extra steps of checking or combining morphemes, or "parse time"; there are some properties of affixed words, however, that can make the decomposition route faster or even mandatory: such as semantic transparency, productivity, neutrality, and frequency interactions. The two routes also facilitate each so when they overlap, activation is overall increased.

In this way, the MRM is able to account for slightly more of the existing data than the AAM. Caramazza et al's (1988) nonword results are explained in this model the same way that they are in the AAM: nonwords with real morphemes take longer to reject because individual morphemes have access representations that become activated, while complete nonsense nonwords have no representations at all. Also, Niemi et al's (1994) results that case-inflected words took longer to process in Finnish than monomorphemic controls can also be explained in the details of the MRM. Unlike most other complex words, common inflections may not have whole-word access representations with each base they attach to according to the MRM. Baayen et al (1997) suggest that such inflections that are very semantically transparent and regular in form and occur quite frequently, but relatively infrequently with any given base. So these affixes never develop whole word representations with many bases, the authors hypothesize; only the most frequent regularly inflected words actually have their own access representations. So there are many instances of inflected words where there is no "race" in terms of the MRM: only the decomposition route is available. For example, case inflections in Finnish are regular and transparent enough and occur often enough with a wide variety of

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[6] Lexical decisions seem to be made based on activation of lemma level in the MRM. More about this below.

bases that they generally must processed via decomposition since they have no whole-word access representations. (Lukatela et al's 1980 results for Serbo-Croatian are consistent with this account as well).

This is also how Baayen et al (1997) explain their results with Dutch plurals. Many of the plurals must be accessed via decomposition, and they show base frequency effects since the morpheme-by morpheme access representations are frequency-sensitive: frequent bases are activated faster than less frequent bases, then their combinability is with the plural is checked and a response can be made. The plurals that have the ambiguous suffix *–en*, however, necessarily developed whole-word access representations, Baayen et al argue, because they are not transparent enough (due to the confusability with the verbal suffix *–en*) to always be accessed via decomposition. Therefore, these do not show base frequency effects, but surface frequency effects due to its effect on the speed of whole-word access.

So the other patterns of base and surface frequency effects, in derivations rather than inflections, found by Bradley (1980), Vannest and Boland (1999), Bertram et al (2000) and Vannest et al (submitted) can be accounted for by the MRM. Recall that in English, Bradley (1980), Vannest and Boland (1999), Vannest et al (submitted) found both base and surface frequency effects for phonologically neutral suffixes in with varying degrees of semantic transparency and productivity: words with *–ment, -ness, -less, -ship –hood,* and *–able*. The presence of base frequency effects, in the context of the MRM, suggests that the decomposition route is being used in to access these words: the morpheme-by morpheme access representations are sensitive to frequency, and when they activate corresponding lemma representations whose combinability facts are used to

make a lexical decision possible, base frequency effects show up in lexical decision times. (Or, in simpler terms, the decomposition route "wins" in these cases). Surface frequency effects result as well, since the whole-word access route is operating in parallel and facilitating the decomposition route. Unlike in the AAM, both types of frequency effects seem to be a direct consequence of the model's architecture. Decomposition is efficient, and therefore faster in these cases of English derivations because, the MRM holds, they have a high enough combination of semantic transparency and productivity, combined with being unambiguous and neutral, so that the decomposition route is effectively facilitated.

In Dutch, Bertram et al (2000) find similar results. They find surface frequency effects only for words in unproductive and ambiguous affixes, but both surface and base frequency effects for complex words with a productive, unambiguous derivational suffix. Affixal homonymy (ambiguity), they also find, seems to overrule productivity and result in surface frequency effects only: the decomposition route is not helped enough in this case. And in Finnish, Vannest et al (submitted) find a complete lack of base frequency effects for derivations, even those that have unambiguous, productive suffixes. They argue that the prevalence of suffixation in Finnish, which has a very rich morphological system, actually makes use of whole-word processing of derived words advantageous, since these derived words usually appear with one or more inflections at the end of the word, which seem to be processed via decomposition, according to the results of Niemi et al (1994) and others. A combination of whole-word access and mandatory decomposition would make it possible for the Finnish language user to avoid double and triple levels of computation on individual words. This would suggest, in terms of the MRM, that the efficiency of the decomposition route (how often it "wins") might actually vary according to language specific-properties.

Moving on from the simple lexical decision data, the priming-in–fragment-completion results of Rueckl et al (1997) and Raveh and Rueckl (2000) are covered in the MRM the same way that they are in the AAM. The letter choices that are made by participants in these experiments are influenced by the words they view in the study task, and morphologically related words prime each other. Raveh and Rueckl (2000) find this for both inflections and derivations, and this makes sense in the MRM because all complex words have morpheme-by morpheme representations that could influence related words in long-term priming: even those that are generally not accessed most quickly via their component morphemes.

The short-term priming data of Marslen-Wilson et al (1994), where derivationally suffixed words and roots only primed each other when their relationship was semantically transparent, is explained in the MRM via feedback from the highest level of representation where semantic information is encoded. Baayen et al (1997) hypothesize that this level of representation, in a priming paradigm, creates feedback that increases the activation of morphological relatives of a given form when they have this semantic information in common: the semantic transparency effect that Marslen-Wilson et al

Author/ Date	Language	Affix Type	Effect	AAM	MRM	Affix-Stripping	Full Listing
Taft and Forster (1975)	English	nonwords w/morpho-logical structure	decomposition (longer RT's for real roots)	X	X	X	
Taft (1979)	English	derivational prefixes/ inflectional suffixes	decomposition (base frequency)	X	X	X	
Bradley (1980)	English	derivational suffixes	decomposition (base frequency) for some suffixes	partial account	X		
Caramazza et al (1988)	Italian	nonwords w/morpho-logical structure	decomposition (longer RT's for real morphemes)	X	X	X	
Marslen-Wilson et al (1994)	English	derivational suffixes	priming for semantically transparent words	partial account	X		
Niemi et al (1994)	Finnish	inflectional suffixes	decomposition (longer RT's for suffixed words)		X	X	
Baayen et al (1997)	Dutch	inflectional suffixes	decomposition (base frequency)	X	X	X	
Vannest & Boland (1999)	English	derivational suffixes	decomposition (base frequency) for some suffixes	partial account	X		
Bertram et al (1999)	Finnish	derivational and inflectional suffixes	decomposition (shorter RT's) for some suffixed words		X		
Raveh & Rueckl (2000)	English	derivational and inflectional suffixes	decomposition (priming for all suffixed words by root)	X	X	X	
Bertram et al (2000)	Dutch	derivational suffixes	decomposition (base frequency) for some suffixes	partial account	X		
Vannest et al (submitted)	English and Finnish	derivational suffixes	decomposition (base frequency) for English, not Finnish	partial account	X		

Table 1. Major findings on morphological processing and whether they can be accounted for by the existing models.

report. This very feedback, Baayen et al explain, is what makes words with certain semantically transparent suffixes, over the long-term, more efficiently processed via decomposition.

Overall, a wide range of data on morphological processing can be covered by the MRM, and factors that, in experiments, seem to influence the presence of differential frequency and priming effects can all be incorporated into the model. This seems to be the greatest shortcoming of the current version of the MRM: it is not well-constrained. Any linguistic factor that seems to have an influence on lexical decision latencies can be added as another potential influence on the speed of the decomposition route, determining whether or not it "wins". The interaction of semantic transparency, affixal homonymy, productivity, and language-specific properties has at this point not been clarified, particularly because many of these factors correlate with each other.

In addition, neither the AAM or MRM make specific claims about the timecourse of morphological effects in word processing or exactly how the lexical decision task is related, in real time, to the proposed processing models. Future experiments (detailed below) hope to make distinctions between the models by examining the timecourse of the lexical decision process.

In general, dual-route models of morphological processing seem to offer good coverage of existing data on morphological processing. The dual-route approach is able to resolve empirical evidence of both whole-word and decompositional processing that could not be covered by earlier models insisting on one or the other. Some problems with the models, that can be addressed in future work include their being too flexible in

accounting for any possible factor that might effect processing, and failing to make specific claims about the timecourse of lexical processing and how it relates to experimental tasks like lexical decision.

2.4 Assumptions of these models in the larger context of word recognition models

These current dual-route models of morphological processing generally do not make any claims about how these processes for handling complex words fit into more general models of word recognition. However, it is possible to make some hypotheses about the cognitive mechanisms that would support the type of architecture that the dual-route models propose for processing the morphological structure of words.

In terms of pre-lexical processing, any visually presented information must first be registered within the visual system. As Johnson et al (2001) explain, this is simply the transferring of light information into a format interpretable by the brain. While the details of such a process will not be included here, it seems relevant to mention that any framework of word recognition begins with a mechanism for making use of visual information.

Second, this visual information must be recoded into a format that is cognitively interpretable: specifically, into orthographic, phonological, and semantic codes. While there is definitely debate about the nature of the units involved in the representation of such information, experimental evidence from subliminal priming suggests that this information is available in some form very early in processing. Most relevant to the current discussion are the orthographic codes; and the morphological processing models we have discussed seem to assume that these are made up of strings of individual letters rather than whole-word representations that would not be separable into morphemes.

Then, these orthographic codes make up the information that is coordinated with the access representations included in the models above. These morphological processing models seem most compatible with a search model of lexical access (the prototypical search model is set forth by Forster 1976). The incoming encoded string of letters is matched up with an existing access representation in the lexicon: a whole-word or morpheme-by-morpheme representation, depending on the morphological structure of the word. (The search model seems to be the assumption of the morphological processing models we have discussed, but they are also not incompatible with an activation model, but the differences will not be detailed here). Once these access representations are selected based on the input, the models proceed as detailed above.

The issues involved in investigating the early stages of word recognition are quite complex, and models of morphological processing are only one part of a larger picture. In the following chapter, we will discuss how data about the timecourse of morphological processing may help to make this part of the picture a little clearer.

CHAPTER 3

THE TIMECOURSE OF MORPHOLOGICAL PROCESSING

3.1 Why study the timecourse of morphological processing?

Neither the Augmented Addressed Morphology Model nor the Morphological Race Model makes explicit claims about cognitive mechanisms underlying the lexical decision task, nor explains directly how activation in each of the models corresponds to the ability to make a response. We can make some assumptions about this information, however, based on explanations of lexical decision data used to support the models. The AAM, for example, expects lexical decisions to be made as early as possible. In Caramazza et al (1988), nonwords with no real morphemes can be rejected more quickly than those that are made of one real and one nonsense morpheme, and those can be rejected more quickly than nonwords made of real morphemes (in illegal combinations). This suggests that the complete nonsense nonwords can be rejected on the basis of having no access representations, and nonwords with one or more real morphemes take longer to reject because they activate morphemic access representations. These nonwords require checking on the combination of morphemes before they can be rejected, though this information is available early, at the access level.

In terms of real words, these can be accepted at the access level as well: known complex words have whole-word access representations, and for unfamiliar complex words, morphemic access representations and information about combinability of morphemes is present at this level as well. Frequency effects also affect access representations, (recall, base frequency affects the AAM's access representations via long-term priming) so the notion that lexical decisions are made right away at the level of access representations is consistent with almost all the lexical decision data. However, one prediction that is made by the AAM with this take on lexical decision is that monomorphemic and complex words that are matched in frequency will have the same lexical decision time. This result is not supported by data from Niemi et al (1994), where complex words had longer RT's, though there are not many cross-linguistic replications of these results. Bertram et al (1999), in fact, found that for some other suffixed words in Finnish, lexical decision times were equal for monomorphemic and derived words. Further tests of this particular prediction by the AAM in other languages would be helpful, to see if this early placement (in terms of first level rather than second) of the lexical decision response is tenable as part of the AAM.

The MRM, in contrast, seems to make the assumption that lexical decision responses to real words and morphemes are made not always at the level of access representations, but after the second level of representation, the lemma level, is activated. The MRM assumes that frequency effects arise at the level of access representations and

that combinatoric information about morphemes is available at the lemma level. So in terms of predictions for nonword rejections, the MRM makes essentially the same predictions for response times that the AAM does: that complete nonsense nonwords can be rejected fastest, since no access representations are present, and nonwords with real morphemes take longer to reject, because they activate access representations and corresponding lemmas. Combinability information has to be checked for the nonwords made of real morphemes, and while this occurs at a higher level in the MRM than it does in the AAM, the predicted pattern of response times is essentially the same.

For real words, the MRM predicts that lexical decision response time will be determined by the fastest access route: whole-word or decompositional. For the whole-word route, lexical decision time is predicted by surface frequency, which affects the speed of activation of whole-word access representations and in turn, lemma representations. So for the whole-word route, lexical decisions might actually be made at the access level. For the decomposition route, the decision must be at the lemma level. Since the speed of both routes can vary, the locus of the lexical decision response in the whole-word route does not affect the model's predictions. For the decomposition route, lexical decision time is predicted by base frequency plus the time it takes to check and re-combine the morphemes. This combinability information is assumed to be available at the lemma level: that is what accounts for the late (in terms of second level rather than first) placement of the lexical decision response in the MRM. The checking and re-combining steps of the decomposition route (Baayen et al's "parse time") can be affected by a number of variables discussed above: affix type, phonology, semantic transparency, affixal homonymy, productivity, and language-specific strategies. If the base frequency is high enough and the parse time fast enough, the decompositions route "wins", and base frequency effects are apparent in lexical decision times.

So while the AAM does not predict a variable appearance of base frequency effects, the MRM predicts that they will appear only in the cases where the decomposition route is used for access: and this should be related to the variables that affect parse time. This seems to be confirmed by the results of Vannest and Boland (1999), Bertram et al (2000) and Vannest et al (submitted), though it is not out of the question that these variables might also be incorporated into the explanation of base frequency effects in the AAM.

One major reason that two models with considerable differences in architecture can account for the same data is that in lexical decision and fragment completion, participants may take as much time as they need to make their decisions, and therefore, modelers may posit any number of steps or levels of representation that must be activated before a lexical decision is made, which cannot be teased apart by the existing data. It seems reasonable, then, that examining lexical decision responses at different points in time during the lexical access process might be informative regarding what information about morphological structure is available when, which would help to discriminate between the dual-route models and constrain them in some way.

This interest in the timecourse of morphological processing was mainly prompted by the pattern of results in Vannest et al (submitted), where base frequency effects were found for derivational suffixes in English, but not in Finnish. While this pattern could indeed be due to cross-linguistic differences in processing strategies, another trend that

we noticed was that overall, the readers of English had longer response times (generally 200-300 ms longer) than the readers of Finnish, and could the pattern of effects be due to the extra processing time that the English readers were taking? While neither of the models predict that base frequency effects occur later than surface frequency effects, such a result would suggest needed modifications to the models that again, might help constrain them further; it also offers more motivation to examine morphological processing at different points in its timecourse.

3.2 A new task: Speeded Lexical Decision

A series of experiments using the lexical decision task in combination with a speed-accuracy tradeoff design[7] offer interesting possibilities for studying the timecourse of morphological effects. In this design, which I will refer to as Speeded Lexical Decision (SLD); participants are trained to make lexical decisions at a faster pace than in the typical subject-paced design (we assume that in this task we are **interrupting** the lexical access process rather than speeding the entire process. See Chapter 7 below for a detailed discussion). This is because they are given a response cue of an auditory signal presented at a controlled interval following the visual letter string, and learn to respond immediately following it. Materials for SLD, then can be set up using the frequency contrast design developed by Taft (1979) and Bradley (1980): sets of words with a given suffix are

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[7] Meyer, Irwin, Osman and Kounios (1988) use a somewhat similar speeded lexical decision task in their more general investigation of the mechanics of speed-accuracy tradeoff and guessing processes. They use a complex timing scheme and a limited number of participants to focus on these issues rather than their implications for lexical processing or architecture. See also McElree (1996) for application of speed-accuracy tradeoff to language studies.

matched as closely as possible in other aspects but contrasted in either base or surface frequency. Effects of these frequency manipulations on lexical decision response latencies are then observed. In SLD, we will be looking for these two types of frequency effects on both response times and error rates in the fast-response condition: lower frequency should result in longer RT's and higher error rates.

3.3 Predictions of the existing models

One important difference, then, between the AAM and MRM models is when information about combinability of morphemes becomes available. In the AAM, this is at the earliest level, which is the access representations, but in the MRM, this is at the second level, the lemma representations.

3.3.1 The Augmented Addressed Morphology Model

In the AAM, this information is expected only to be needed in the case of unfamiliar words that do not have whole-word representations: but the crucial prediction of the AAM is that all the information that affects lexical decision times to complex words is located at the access level. This suggests that we should see the **same pattern of effects no matter how quickly** people perform the lexical decision task: as soon as

they have enough information to make accurate lexical decisions, they can be affected by base and surface frequency, as well as, in the case of unfamiliar words, whether or not the morphemes can legally be put together.

For example, in the case of the English derivational suffixes *–ity*, *-ness*, and *-able*, examined in Vannest and Boland (1999) and Vannest et al (submitted) we found base and surface frequency effects for *-ness* and *-able*, but only surface frequency effects for *-ity* in regular subject-paced lexical decision. The AAM predicts that we would find this same pattern at any speed (though, as mentioned earlier, it does not account for the variable appearance of base frequency effects). This is due to the use of whole-word access representations for all known suffixed words -- and lexical decisions based on them. The same should therefore be true for other derivations as well as inflections, such as English past tense, according to this model. See Figure 3 for some graphic representations of these predictions.

3.3.2 The Morphological Race Model

In the MRM, words that are processed via the decomposition route cannot be verified in lexical decision until the lemma level is activated, since this is where combinatoric information becomes available. Complex words that are normally accessed quickly via the whole-word route could potentially be decided upon earlier based on access representations, but those that are best processed via decomposition cannot be completely verified immediately at the access level. So the MRM predicts that when the lexical decision task is speeded, words accessed via whole-word representations should not necessarily be affected provided there is enough time to activate the access level, but decisions on words that use decompositional access should not be verified as accurately, or at least would show a different pattern of responses when the access process is interrupted early. It is also possible that words normally best processed on a morpheme-by-morpheme basis in the MRM might be verified in SLD on the basis of whole-word access representations (since most suffixed words have both kinds of access representation in the MRM). If this were the case, we might expect accurate verifications in fast-speed conditions, but a lack of base frequency effects.

So for the suffixes discussed above, the MRM model would predict for *–ity* (for which we found no evidence of decomposition in traditional lexical decision) that we would again find solely surface frequency effects across any speed conditions, since these words are best accessed on the basis of whole word access representations. For phonologically neutral derivations like *-ness* and *-able*, however, we found base frequency effects in previous studies, which suggest that they are best processed via the decomposition route. Therefore, when the access process is interrupted early (by assumption, at the level of access representations), combinability information needed to verify the morpheme-by-morpheme representations is not available, according to the MRM. The model predicts, therefore, two possibilities. First, that lexical decisions would be less accurate for *-ness* and *–able* -type words at fast speeds, because the reader cannot yet verify that suffixes like *-ness* and *-able* can actually legally combine with any root if he/she only works according to decomposed access representations. Accuracy would improve at slower speeds when the lemma level can be activated and combinability information checked. The second possibility is that very fast lexical decisions on *-ness* and *-able* words are made according to their corresponding whole-

word access representations (normally the less efficient access route). Verifications would therefore still be accurate but no base frequency effects would occur at fast speeds, since base frequency effects result from decomposed access representations according to the MRM. They could show up at slower speeds, however, when the lemma level has time to be activated and the lexical decisions could be made there based on the decomposition route as in normal subject-paced lexical decision. This change in response pattern across speeds is predicted by the MRM and not the AAM.

For common inflections, such as past tense *–ed* the MRM holds that these have decomposed representations only. So in the SLD task, if the access process can be interrupted at the level of access representations, it should not be possible to accurately verify these suffixed words since combinability information is not yet available, and they have no corresponding whole-word representations to rely on. This is in contrast to the predictions of the AAM, which predicts consistent effects for all known inflected and derived words. See Figure 4 for some graphic representations of these predictions.

In the following two chapters, three experiments making use of the Speeded Lexical Decision Task are presented.

CHAPTER 4

SPEEDED LEXICAL DECISION EXPERIMENTS -- DERIVATIONAL SUFFIXES

4.1 Experiment 1: *-ity, -able*, and *–ness*

The experiments in Chapters 4 and 5 make use of the Speeded Lexical Decision methodology described above, and examine a variety of suffixes in English: several derivations in Chapter 4, and in Chapter 5, the inflection *–ed*. The derivational suffixes were studied in a series of two experiments detailed below.

4.1.1 Method

Materials. The stimuli in this study were some of the derivationally suffixed words in English that were used in Vannest and Boland (1999) and Vannest et al (submitted) with *-ity*, *-ness* and *-able*, that were set up in base and surface frequency contrasts: frequency counts are from the MRC psycholinguistic database, Coltheart, 1981, containing about one million word tokens from the counts of Kucera and Francis, 1967. Specific frequency information for these stimuli is included in Table 2. Base Frequency was tabulated through use of a script that searched the MRC database (Johnson 2000) for items with a given base. All the items were verified by the user that they indeed

contained that base, and then their frequencies were summed (including that of the base as a freestanding word) to determine the base frequency. The script is included in Appendix 1.

suffix	n	Mean Base Frequency	Mean Surface frequency
-ity, high surface	10	162.3	63.5
-ity, low surface	10	129.3	4.6
-ity, high base	10	192.7	7.7
-ity, low base	10	12.6	7
-ness, high surface	10	152	31.9
-ness, low surface	10	155	1.9
-ness, high base	10	287	2.1
-ness, low base	10	22	1.8
-able, high surface	15	211	30.2
-able, low surface	15	201	0.9
-able, high base	15	266	6.3
-able, low base	15	35	6.5
monomorphemic, high	20	n/a	110.5
monomorphemic, low	20	n/a	1.95

Table 2. Frequency Information for Items in Experiment 1.

There were 15 items in each condition for *-able* and 10 in each for *-ity* and *-ness* due to frequency-matching constraints, and 40 monomorphemic real words of comparable length, 20 of high frequency and 20 of low frequency. Included as fillers were: 130 pronounceable nonwords, (5 with each of the real suffixes being investigated in the experiment (15 total) so that subjects could not make a lexical decision simply based on the presence of the suffix), and also 10 further real word fillers with suffixes not being investigated in the experiment. The critical items are included in Appendix 2.

Procedure. The stimuli were presented in the center of a computer screen in white capital letters on a black background, and each was preceded by a 500 ms fixation mark of three asterisks. Participants made their lexical decision responses by pressing YES or NO buttons on a Psychology Software Tools response box and the stimulus disappeared upon each response. To influence the speed of responses, an auditory response cue (a computer-generated beep) was generated at one of four time delays measured from the onset of presentation of the visual stimulus: 150 300, 500, & 700 ms.

Each stimulus item appeared on each of four experimental lists in a different delay condition on each list. Stimuli in each delay condition were distributed evenly across the four lists and were presented in random order within each list. Data was collected from 40 participants (10 for each experimental list).

Participants were instructed to respond immediately after the response cue, specifically, at least faster than 300 ms after the beep. After each trial, they were given feedback on the computer screen about the timing of their response. Each participant completed a 10-minute practice session preceding the experimental session, where

stimuli were words with a variety of frequency values and morphological structures. In total, each participant spent about 30 minutes completing the experiment. See Figure 5 for a schematic of the task.

Participants. Participants were 40 undergraduates and native speakers of English with normal or corrected vision, who received course credit for their participation.

4.1.2 Results and Discussion

Error Rates. Overall, errors decreased as response delay increased (speed-accuracy tradeoff). An analysis of variance showed a main effect of response delay [F1(3,36)=41.9, p<.05; F2(3,176) =31.0, p<.05]. Overall error rates were as follows: for the 150 ms response delay, 17.5%; for the 300 ms response delay, 10.3%, for the 500 ms response delay, 7.8%; for the 700 ms response delay, 5.5%.

Monomorphemic words showed frequency effects on error rates across response delays, and an analysis of variance yielded a main effect of response delay on the error rates [F1(3,36)=16.5, p<.05; F2(3,36)=14.8, p<.05], as well as a main effect of frequency across all the time delays[F1(1,38)=114.5, p<.05; F2(1,38)=116.5, p<.05]. (See Figure 6).

In the case of the suffixed words, the *-ness* words were the only ones that showed effects of frequency on error rates[9]: there were surface frequency effects for *–ness* words at the 150 ms and 500 ms response delays (For the 150 ms delay condition, [t1(39)=2.61,

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[9] There was also a slight base frequency effect for *-able* words in the 300 ms delay condition: [t1(39)=2.53, p<.05, marginal by items, t2(28)<.10)

p<.05; t2(18)=4.20, p<.05]; for the 500 ms delay condition, [t1(39)=2.94, p<.05; t2(18)=3.62, p<.05]), and also a base frequency effect in the 300 ms delay condition [marginal by subjects, t1(39)=1.91, p=.06; t2(18)=2.21, p<.05] (See Figure 7).

Response Times for Correct Verifications. Monomorphemic words showed frequency effects on response time at three out of four response delays (For the150 ms delay condition, [t1(39)=5.25, p<.05; t2(38)=5.48, p<.05]; for the 300 ms delay condition, [t1(39)=4.57, p<.05; t2(38)=4.15, p<.05]; for the 500 ms delay condition, [t1(39)=2.87, p<.05; t2(38)=3.48, p<.05]. (See Figure 8).

Again, there were only surface frequency effects on response time for *-ity* words, at the short response delay of 300 ms [t1(39)=2.33, p<.05; t2(18)=2.81, p<.05] (though there was a trend toward a base frequency effect at 150 ms). (See Figures 9 and 10).

For *-able* words, there were base frequency effects on response time across response delays, (For the 150 ms delay condition, [t1(39)=2.22, p<.05; t2(28)=2.80, p<.05]; for the 300 ms delay condition, [t1(39)=2.52, p<.05; t2(28)=2.07, p<.05]; for the

700 ms delay condition, [t1(39)=2.76, p<.05; t2(28)=2.36, p<.05]), and surface frequency effects at the 150 ms delay only [t1(39)=2.00, p=.05; t2(28)=2.06, p<.05]. (See Figures 11 and 12).

There were no frequency effects on RT for *–ness* words except one weak surface frequency effect at 700 ms delay [marginal by subjects, t1(39)=1.76, p<.10; t2(18)=2.22, p<.05]. (See Figures 13 and 14).

These results suggest differences in the timecourses of the decompositional and whole-word processing routes. If the lexical decisions were being made based on default whole-word access representations that are also sensitive to base frequency, as the AAM suggests, we would expect base and surface frequency effects even when lexical decisions are made quickly, and the pattern of results in this experiment are consistent with such an account. However, if this type of access representation is indeed being used, we might expect these frequency effects to persist no matter the speed of the response. If whole-word and decompositional access are proceeding in parallel, as the MRM holds, however, we would not expect base frequency effects to show up at very fast speeds; decomposed access representations could not be used to make lexical decisions at the access level, since information about the combinability of morphemes would not be available then, according to this model. Both the *–ness* and *–able* words showed some effect of base frequency at short response delays, suggesting that the system may be sensitive to base frequency very early in the access process. However, why does this effect persist across time delays for *–able* words but not for *–ness* ones?

Consistent with the standard lexical decision results of Vannest and Boland (1999), *-ity* words, which have a phonologically non-neutral (and therefore, perhaps less-decomposable) suffix, only surface frequency effects were found: no evidence of a decomposition process. Again, this effect does not persist across response delays.

The frequency effects for monomorphemic words, on both response times and error rates, that we found across time delays verify that lexical frequency effects can indeed be detected in the speeded lexical decision task; but their variable appearance when complex words are used as stimuli suggests that frequency effects do indeed interact with morphological processing. Below, we examine this interaction further with an experiment involving three more English derivational suffixes.

4.2 Experiment 2: *-less*, *-ship*, and *hood*

4.2.1 Method

Materials. The stimuli in this study were some of the derivationally suffixed words in English that were used in Vannest and Boland (1999) and Vannest et al (submitted) with *-less*, *-ship*, and *hood*, that were set up in frequency contrasts as described in Experiment 1 (Specific frequency information for these stimuli is included in Table 3).

suffix	n	Mean Base Frequency	Mean Surface Frequency
-less, high surface	8	255	19
-less, low surface	8	234	1.4
-less, high base	8	228	4
-less, low base	8	21	3.8
-ship, high base	10	164	8.7
-ship, low base	10	29	10.3
-hood, high base	10	314	2
-hood, low base	10	22.4	0.5

Table 3. Frequency Information for Items in Experiment 2.

There were 8 items in each condition for *-less* and 10 in each for *-ship* and *-hood* due to frequency-matching constraints. For the *–less* words, both base and surface frequency contrast pairs were used, but due to a lack of high-surface frequency *-ship* and *–hood* words in English, only base-contrast pairs were could be constructed. Included as fillers were: 76 pronounceable nonwords, (10 total with the real suffixes being investigated in the experiment so that subjects could not make a lexical decision simply based on the presence of the suffix), and also 24 monomorphemic real words of comparable length. The critical items are included in Appendix 3.

Procedure. This was the same as in Experiment 1.

Participants. Participants were 36 undergraduates and native speakers of English with normal or corrected vision, who received course credit for their participation.

4.2.2 Results and Discussion

Error Rates. Overall, errors again decreased as response delay increased (speed-accuracy tradeoff). An analysis of variance showed a main effect of response delay [F1(3,36)= 4.62, p<.05; F2(3,140) =2.61, p<.05]. Overall error rates were as follows: for the 150 ms response delay, 17.5%; for the 300 ms response delay, 13.3%; for the 500 ms response delay, 11.5%; for the 700 ms response delay, 11.1%.

The *–less* words showed frequency effects on error rates across response delays. There were effects of base frequency at the 150 ms delay [t1(35) = 2.98, p<.05, t2(14) = 2.30, p<.05]; at the 300 ms delay [t1(35) = 5.28, p<.05, t2(14) = 3.65, p<.05]; at the 500

ms delay [t1(35) = 3.18, p<.05, t2(14) = 3.77, p<.05], and at the 700 ms delay [t1(35) = 3.04, p<.05, t2(14) = 2.53, p<.05]. (See Figure 15). There was also an effect of surface frequency on the *–less* words. This was present at the 300 ms delay [t1(35) = 2.69, p<.05, t2(14) = 2.72, p<.05]; marginal by items (p<.10) at the 500 ms delay; and was found at the 700 ms delay [t1(35) = 2.65, p<.05, t2(14) = 2.75, p<.05]. (See Figure 16).

The *-ship* and *-hood* words showed fewer and weaker effects on error rates. For *-ship* words, where only base-contrast pairs were available, there was a frequency effect at the 150 ms delay, significant by subjects only [t1(35)=2.29, p<.05]. The *-hood* words, where again solely base-contrast pairs were tested, there was a frequency effect on error rates at the 500 ms delay, also significant by subjects only [t1(35)=2.62, p<.05].

Response Times for Correct Verifications. The *–less* words showed an effect of base frequency on response times, but only at the 300 ms response delay [t1(35) = 2.32, p<.05, t2(14) = 4.11, p<.05]. (See Figure 17). An effect of surface frequency was also found at the 300 ms delay [t1(35) = 2.47, p<.05, t2(14) = 2.06 p<.05]. (See Figure 16).

-ship words, for which only base-contrast pairs were available, showed significant effects of base frequency at the 300 ms delay [marginal by subjects, t1(35) = 1.91, p =.06, t2(18) = 2.35 p<.05]; and also at the 500 ms delay [t1(35) = 2.73, p<.05, t2(18) = 2.66 p<.05]. (See Figure 19). Also, *-hood* words, for which likewise only base-contrast pairs

were available, showed significant effects of base frequency at the 150 ms delay [marginal by subjects, t1(35) = 1.88, p =.06, t2(18) = 2.54 p<.05]; and also at the 300 ms delay [significant by items only, t2(18) = 2.04 p<.05]. (See Figure 20).

These results, like those of Experiment 1, show a pattern inconsistent with either of the processing models from which we have drawn predictions. *–less* words showed effects of both base and surface frequency, and *-ship* and *–hood* words showed effects of base frequency at short time delays, but these did not persist at all time delays, which would have been consistent with the AAM. However, base frequency effects across the different suffixed words did appear when people responded quickly, which is does not support the predictions of the alternative model, the MRM, where combinability information about morphemes is not available early in processing.

A modified version of these models that takes into account the early sensitivity of lexical representations of complex words to both base and surface frequency, while still accounting for the variable appearance of these effects over time seems to be an appropriate way to account for these data. This possibility will be discussed further in Chapters 7 and 8 below.

In the following chapter, we consider an inflectional suffix, for which the MRM model makes slightly different predictions.

CHAPTER 5

SPEEDED LEXICAL DECISION EXPERIMENTS -- INFLECTIONAL SUFFIXES

5.1 Experiment 3: *-ed*

Inflected words offer a further testing ground for the dual-route models of morphological processing that have been proposed.

Recall, the AAM holds that all the information that affects lexical decision times to complex words is located at the access level. This suggests that we should see the **same pattern of effects no matter how quickly** people perform the lexical decision task: as soon as they have enough information to make accurate lexical decisions, they can be affected by base and surface frequency, as well as, in the case of unfamiliar words, whether or not the morphemes can legally be put together. This should be true for derivations as well as inflections, such as English past tense, according to this model.

For common inflections, such as, *–ed* the MRM holds that these have decomposed representations only. If the access process can be interrupted at the level of access representations in the speeded LD task, it should not be possible to accurately verify these suffixed words since combinability information is not yet available, and they have no corresponding whole-word representations to rely on. This is in contrast to the predictions of the AAM, which predicts consistent effects for all known inflected and derived words.

5.1.1 Method

Materials. The stimuli in this study were words with *–ed* that were set up in frequency contrasts (frequency counts are from the MRC psycholinguistic database, Coltheart, 1981, containing about one million word tokens from the counts of Kucera and Francis, 1967. Specific frequency information for these stimuli is included in Table 4).

suffix	Mean Base Frequency	Mean Surface frequency
-ed, high surface	163.27	55.8
-ed, low surface	162.87	3.07
-ed, high base	148.73	1.13
-ed, low base	5.73	1.07

Table 4. Frequency Information for Items in Experiment 3.

There were 15 items in each condition for the *–ed* words. Included as fillers were: 50 pronounceable nonwords, (7with the real suffixes being investigated in the experiment

so that subjects could not make a lexical decision simply based on the presence of the suffix), and also 20 other real words of comparable length. The critical items are listed in Appendix 4.

Procedure. This was the same as in Experiment 1.

Participants. Participants were 36 undergraduates and native speakers of English with normal or corrected vision, who received course credit for their participation.

5.1.2 Results and Discussion

Error Rates. Overall, errors decreased as response delay increased (speed-accuracy tradeoff). An analysis of variance showed a main effect of response delay [F1(3,36)=9.66, p<.05; F2(3,56) =7.02, p<.05]. Overall error rates were as follows: for the 150 ms response delay, 10.6%; for the 300 ms response delay, 6.5%, for the 500 ms response delay, 3.9%; for the 700 ms response delay, 3.0%. These –ed words showed base frequency effects on error rates at the 150 ms delay [t1(35)=3.26, p<.05; t2(28) = 3.06, p<.05] and also at the 500 ms delay [t1(35)=2.19, p<.05; t2(28) = 2.56, p<.05], but no effects of surface frequency. (See Figures 19 and 20).

Response Times for Correct Verifications. There were no effects of frequency on correct response times to *–ed* words.

This pattern of effects is for a large part consistent with the dual-route models we have discussed. These *-ed* words induce effects of base frequency across the three shortest response delays (significant effects at 150 and 500 ms).

Both models predict that inflected words will be very sensitive to base frequency. The MRM, in particular, suggests that inflected words are accessed solely via decomposed access representations. Such an explanation fits nicely with the presence of base frequency effects and complete lack of surface frequency effects on the present experiment. The AAM, which hinges on the use of whole-word access representations by default for known words, predicts that surface frequency effects should appear also. So while the preceding data from Experiments 1 and 2 on derived words seemed better accounted for by the AAM, the MRM seems to make better predictions for inflected words.

An interesting question is why the effect of base frequency on the processing of *-ed* words was apparent in the error rates and not the response times. Specifically, when these *-ed* words were of low base frequency, readers made significantly more errors rather than responding correctly yet more slowly. This suggests that, assuming these

inflected words were being accessed by decomposed morpheme-by-morpheme representations, perhaps the combinability information about the component morphemes was not available quickly enough when responses had to made under time pressure. This is also consistent with the architecture of the MRM, where this information is not proposed to become available until the higher level of processing, the lemma level. However, this is also not inconsistent with the AAM, since base frequency contributes to the activation of access representations. However, the appearance of frequency effects on error rates and not response times is not directly predicted by this model.

Recall that in our examination of derivational suffixes, *-ness* words in Experiment 1 showed some frequency effects on error rates and not response times, and the *-less* words in Experiment 2 showed effects on both error rates and response times. The relationship between error and response time effects and the processing models will be discussed further in Chapter 7.

In the following chapter, an alternative speeded task will be used to reexamine the lexical access of some of the derivationally suffixed words considered above. With a speeded naming task, we may find similar patterns of base and surface frequency effects and have evidence that they are not specific to the lexical decision methodology. This will offer an opportunity to observe the interaction of decompositional and whole-word processing with different lexical access tasks.

CHAPTER 6

AN ALTERNATE SPEEDED METHODOLOGY - NAMING

6.1 Experiment 4: Naming *-ity*, *-able*, and *–ness*

In the series of experiments above, we have concentrated so far on the lexical decision task, which has been so prevalent in work on morphological processing; comparing these lexical decision results to some results using another task would be very informative about the nature of lexical decision results, and whether the stimulus effects are specific to this single task. The naming task, where participants respond to a visually presented item by reading it aloud, has also been used in studies of lexical processing: though not specifically applied to morphological processing. Frequency effects have indeed been observed in naming: previous work, for example Grainger (1990), Schilling, Rayner and Chumbley (1998), or Morrison and Ellis (2000) show evidence of frequency effects both in lexical decision and naming. In general, these authors find that frequency effects are smaller in naming than in Lexical Decision. As Grainger (1990) explains, theories of visual naming have suggested words can be named via access to their lexical representations, but also through sublexical grapheme-to-phoneme conversion rules, which may serve a facilitative role for the naming of words with regular pronunciations.

Specifically, frequency effects may be somewhat attenuated in naming because there is an influence on naming times of sublexical rules of pronunciation that may not be modulated by lexical frequency. However, frequency effects are not absent in naming, so manipulations of base and surface frequency in suffixed words should also affect response times in this task. More discussion of the differences between lexical decision and naming will be included in subsequent chapters.

In this chapter, we suggest that the speed of naming responses could also be controlled by means of a response cue, and therefore morphological effects in naming could be compared to those in lexical decision at different points in the timecourse of processing. Kello and Plaut (2000), for example, used a version of the naming task where they trained participants to control the speed of their response by setting a tempo for the response (based on a series of rhythmic cues). They were looking for effects of frequency and of spelling-sound consistency on naming latencies for monomorphemic words, and found that these effects were reduced in magnitude, but still present when responses were speeded, and these authors emphasize the ability of readers to exercise strategic control over the speed of their responses.

Overall, a pattern of base and surface frequency effects at different speeds that is similar across naming and lexical decision would help to verify that the models that base their architecture mainly on lexical decision data are not restricted in explanatory power to that single task.

6.1.1 Method

Materials. The stimuli in this study were the same as in Experiment 1:some of the derivationally suffixed words in English that were used in Vannest and Boland (1999) and Vannest et al (submitted) with *-ity*, *-ness* and *-able*, that were set up in base and surface frequency contrasts. Specific frequency information for these stimuli is included in Table 2, in Chapter 4).

Recall from Experiment 1 that there were 15 items in each condition for *-able* and 10 in each for *-ity* and *-ness* and 40 monomorphemic real words of comparable length, 20 of high frequency and 20 of low frequency. Included as fillers were 50 additional real words with a range of frequency values and a variety of morphological structures.

Procedure. The stimuli were presented in the center of a computer screen in white capital letters on a black background, and each was preceded by a 500 ms fixation mark of three asterisks. Participants made their naming responses by pronouncing the presented words into a head-mounted Shure SM10H microphone set up with a Symetrix 2-channel microphone pre-amp, and responses were detected through the voice key of a Psychology Software Tools button box. The stimulus disappeared upon each response. To influence the speed of responses, a visual response cue, of a line of 10 asterisks centered on the line directly beneath the stimulus, was generated at one of four time delays measured from the onset of presentation of the visual stimulus: 150, 300, 500, & 700 ms.

Each stimulus item appeared on each of four experimental lists in a different delay condition on each list. Stimuli in each delay condition were distributed evenly across the four lists and were presented in random order within each list. Data was collected from 40 participants (10 for each experimental list).

Participants were instructed to respond immediately after the response cue. After each trial, they were given feedback on the computer screen about the timing of their response in terms of time elapsed from the response cue. Each participant completed a 5-minute practice session preceding the experimental session, which took about 20 minutes.

Participants. Participants were 40 undergraduates and native speakers of English with normal or corrected vision, who were paid or received course credit for their participation.

6.1.2. Results and Discussion

All naming responses were considered in these analyses. Since participants were not recorded, missing data or error types were not analyzed. However, naming accuracy was extremely high in this experiment, based on the experimenters' observations, and errors are assumed not to have an influence on the overall pattern of effects.

Naming Response Times. Monomorphemic words showed frequency effects on response time at three out of four response delays (For the150 ms delay condition, [t1(39)=5.51, p<.05; t2(38)=4.86, p<.05]; for the 300 ms delay condition, [t1(39)=5.21, p<.05; t2(38)=3.93, p<.05]; for the 500 ms delay condition, [t1(39)=5.25, p<.05; t2(38)=5.96, p<.05]. (See Figure 23).

Again, there were only surface frequency effects on response time for *-ity* words, at the shortest three response delays. For the150 ms delay condition, [t1(39)=2.68, p<.05; t2(18)=2.62, p<.05]; for the 300 ms delay condition, [t1(39)=3.71, p<.05; t2(18)=3.02, p<.05]; for the 500 ms delay condition, [t1(39)=2.93, p<.05; t2(18)=2.93, p<.05]. (See Figures 24 and 25). For *-able* words, there were base frequency effects on response time at the first two response delays, (For the 150 ms delay condition, [t1(39)=4.95, p<.05; t2(28)=3.85, p<.05]; for the 300 ms delay condition, [t1(39)=4.54,

p<.05; t2(28)=2.77, p<.05]. See Figures 26 and 27). There was one frequency effect on RT for *–ness* words: a surface frequency effect at the 150 ms delay [t1(39)=3.81, p<.05; t2(18)=2.60, p<.05]. (See Figures 28 and 29).

These results from Speeded Naming are consistent to some degree with the speeded lexical decision results presented in preceding chapters. Overall, unlike in other studies comparing these tasks frequency effects were not noticeably smaller, and also they appeared for several sets of items in this experiment. First, we found very similar effects of frequency on monomorphemic words, indicating that this task, like speeded lexical decision is sensitive to differences in lexical frequency.

For *–ity* words, we again found surface frequency effects when participants were responding quickly. While the models would predict this effect would be present across response delays, it does disappear when responses are made after 700 ms. However, the lack of base frequency effects for *–ity* is nicely consistent with all previous evidence.

For *–able* words, where we found effects of both base and surface frequency in lexical decision even at the shortest response delays, we find only base frequency effects in speeded naming. This pattern is not predicted by either processing model we have discussed: the MRM suggests that base frequency effects should not be detectable early in processing when combinability information about morphemes is not available.

However, since the AAM uses whole-word access representations by default that are sensitive to base frequency, this model would predict both kinds of effects for *–able* words.

-ness words presented a somewhat different pattern in Speeded Naming than in Speeded Lexical Decision. They show surface frequency effects in both tasks, but in naming, the effect appears only at short response delays, and in lexical decision it is also present at longer delays. Also, the early base frequency effect found on error rates in lexical decision did not appear in naming. This early sensitivity to surface frequency is not inconsistent with the existing models, but the lack of base frequency effects is not predicted by either.

The following two chapters offer some further analysis of these lexical decision results. First, we will consider how the speeded responding in these tasks might be interacting with the role of morphological structure in lexical access of these words: responding under time pressure may have different effects on the processing of different types of suffixed words, and it also may effect the two tasks we have used in dissimilar ways. In addition, we will consider how the existing processing models can be modified to better capture the data presented above.

CHAPTER 7

STRATEGIC CONTROL IN SPEEDED TASKS

Before discussing the implications of the above results for models of morphological processing, this chapter will address issues of strategic control in the use of speeded tasks such as the Speeded Lexical Decision and Speeded Naming demonstrated above. Clearly, participants' response times in these experiments are influenced by the response cue, and participants can make a conscious effort to time their response according to the cue. However, properties of the stimuli, in this case lexical frequency and morphological structure, interact with the influence of this cue to affect response times. Recall, for instance, Kello and Plaut (2000) use a tempo-naming task, where participants were asked to make speeded naming responses by timing their response according to a previously presented tempo. They report that participants could not time naming responses solely based on the presence of a response cue: other factors were necessarily influencing response times. So what is really going on when we ask participants to perform a complex task like reading at an unusually quick speed? Below, we will consider a few possibilities for how participants' ability to exercise some strategic control over their performance in a speeded task might interact with their normal processing in, for example, lexical decision or naming.

7.1 Interrupting the process: Strategic control of response execution

The interaction of timing control and the processing of complex words that we have assumed in the sets of predictions and discussion above is that it is possible to interrupt a lexical access process in progress and get a response based on the information available to the participant at that point in the partially completed process. Meyer, Irwin, Osman and Kounios (1998), formalize this hypothesis in their Parallel-Sophisticated Guessing (PSG) model. They suggest that in the context of a speeded task, participants maintain a cumulative record of the partial information they have about a stimulus in order to make a well-informed guess if necessary. This model is based on a series of assumptions: that guessing is triggered by detecting the response cue, and that it makes use of any available partial information. Also, this model assumes that normal processing continues independently of the guessing process, but responses in a task are a result of one process or the other: "sophisticated" guessing, or normal processing if time

allows. Results showing higher error rates when responses are made quickly are well accounted for by this model because guesses made based on partial information are likely to be inaccurate.

Jared (1997) takes a similar view by suggesting that in naming, participants set a response criterion for the timing of their naming response that may be affected by the conditions of the experiment (i.e. in Jared's 1997 studies, the composition of the lists of items varied, and she suggested that lists that contained on average more difficult items induced readers to set a later criterion). Participants may, if necessary, make responses at varying points in processing when varying amounts of information are available: they strategically control the timing of the execution of their response according to the demands of the task.

7.2 Speeding the entire process: Strategic compression of processing

An alternative account of strategic control of response timing and its interaction with the processing of words is that rather than interrupting the normal course of processing and making a response based on the information available at the time, the entire normal process may be completed in a shorter time span when the participant is under time pressure in a given task.

Kello and Plaut (2000) hypothesize that within the context of their tempo-naming task, participants compress the lexical access process so that a response can be made as close as possible to the appropriate moment. As supporting evidence, they found that lexical frequency effects were somewhat attenuated in this task, and suggest that the compression of processing times overall accounts for the decreased differences in processing times due to characteristics of the stimuli. These authors implement this notion in a connectionist framework in terms of increased input gain, which might be interpreted as increased energy or attention given to performing the task. They note that increased input gain amplifies any noise in processing, which they suggest accounts for the higher error rates that they found when responses were made very quickly.

In addition, Kello and Plaut (2000) contrast their "gain hypothesis" with the time-criterion hypothesis set forth above (by Jared 1997 and others); they write, "The time criterion halts the normal trajectory of processing at a particular point in time, whereas input gain accelerates or decelerates the trajectory of processing".

Both the interrupted and the compressed processing hypotheses can predict speed-accuracy tradeoff in a speeded task, as we found in the Speeded Lexical Decision and Speeded Naming tasks above.

7.3 Altering the process: Strategic de-emphasis in a dual-route model

Whether we accept that processing in speeded tasks in interrupted or compressed, a further possibility for the interaction of strategic control over response timing and the processing of complex words is the strategic use of one processing route over another.

While such a hypothesis has not been applied to dual-route models of morphological processing in any of the previous literature, it has been debated in the context of dual-route models of naming.

Specifically, models of naming propose words can be named via access to their lexical representations, but also through sublexical grapheme-to-phoneme conversion rules, which may serve a facilitative role for the naming of words with regular pronunciations. However, this sublexical route is assumed not to be sensitive to word frequency, and therefore results in some attenuation of frequency effects in naming tasks. Herdman (1992) explains that use of the sublexical route is hypothesized to be under strategic control based on the conditions of a given experiment, i.e. when a high percentage of words with low grapheme-to-phoneme correspondence are presented, this route may be "turned off". Herdman (1992) uses a dual-task paradigm to examine attentional demands in lexical decision and naming, and hypothesizes that a major role of attention in participants' performance of a naming task may be to modulate the level of attentional resources devoted to one route or the other. If the sublexical route for naming is not helpful for the naming of a particular set of stimuli, this route is strategically de-emphasized, and the attention devoted to it is decreased.

In the context of a speeded task demanding performance of dual-route processing, it seems reasonable that attention might be strategically allotted to one route or another, and a route that is not as helpful for accurate execution of the task might be de-emphasized. Specifically, for speeded responses to suffixed words as we have collected in the present series of experiments, participants may be devoting additional attention to whole-word or decompositional processing to help them perform lexical decision or naming while under time pressure. We will return to this issue when reviewing the experimental results in Chapter 8 below.

7.4 Assumptions for the interpretation of the present results: Interruption vs. Compression

In interpreting the results from the present series of experiments using speeded tasks, I propose to adopt a compromise between the "interruption" or response criterion hypothesis, and the "compression" or input gain hypothesis, since they do not seem to be clearly distinguished by the existing data. Both possibilities can account for the presence of stimulus effects (e.g. lexical frequency effects) in speeded tasks, as well as increased error rates as responses are made more and more quickly.

Therefore, for the purposes of the present studies, we will assume that processing is compressed to some degree, perhaps characterized as increased input gain. But it can also be interrupted: there is a limited extent to which processing can be compressed, and if responses are cued early enough in processing, a response may be made based on the partial information that is available at the time. So at least at the earliest response delays in the experiments presented above, we will assume that we are tapping into responses based on the information that is available in the early stages of the lexical access process.

In terms of Meyer et al's PSG model, there seems to be no reason to posit an independent record of partial information for the purposes of guessing, separate from the normal accumulation of information in processing words. Also, the PSG model assumes

that any response made in a speeded task that is made more quickly than a comparable response in a non-speeded task (such as standard lexical decision) is **definitely** a guess: since the process is not compressed overall in time.

Many of the response times in the Speeded Lexical Decision experiments here are indeed shorter, particularly at the 150 and 300 ms and sometimes even 500 ms delays[10], than those we found in standard lexical decision experiments in Vannest and Boland (1999) and Vannest et al (submitted). While it is likely that these quick responses actually are "educated guesses" made on the basis of the information that is available early in processing, we will not assume in the present study that they are simply because they are shorter responses in the standard lexical decision. In standard lexical decision, participants may not be making fully complete, accurate responses as quickly as they are able to - this was part of the original inspiration for the speeded task.

So overall, we will assume that normal processing can be interrupted through use of a speeded task, and that highly speed responses reflect an early state of the processing system rather than processing completed much more quickly. However, this does not preclude processing from being somewhat compressed into a shorter timespan that it would take without the presence of a response cue.

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[10] Consider these response times as measured from the onset of the visual presentation of the stimuli, as they are measured in standard lexical decision.

CHAPTER 8

IMPLICATIONS FOR LEXICAL ARCHITECTURE BASED ON THE TIMECOURSE OF MORPHOLOGICAL PROCESSING

In this final chapter, we will first review the results of the Speeded Lexical Decision and Naming experiments presented in chapters 4,5 and 6, and also, how they coincide with the existing models of morphological processing we have discussed. Then, I will present an additional model that combines features of the Augmented Addressed Morphology and Morphological Race Models, and takes into account overall patterns in the data collected here about the timecourse of processing complex words. The results of the present series of experiments will again be discussed, in the context of this model.

8.1 Summary of the Speeded Lexical Decision and Naming Results

8.1.1 Speeded Lexical Decision

In Experiment 1, frequency effects resulted for monomorphemic words on both response times and error rates, across the shortest three time delays. This verifies that lexical frequency effects can indeed be detected in the speeded lexical decision task Also in this experiment, both the *–ness* and *–able* words showed some effect of base frequency

at short response delays, suggesting sensitivity to base frequency early in the access process. The effect persisted across time delays for *–able* words, but not for *–ness* words. Also, the effects on *-ness* words were found on error rates and not response times.

For *-ity* words, which, recall, have a phonologically non-neutral (and therefore, perhaps less-decomposable) suffix, only surface frequency effects were found: no evidence of a decomposition process, which is consistent with the standard lexical decision results of Vannest and Boland (1999), Again, this effect disappeared at longer response delays.

In Experiment 2, *–less* words showed effects of both base and surface frequency, affecting error rates at all response delays and response times at short delays and *-ship* and *–hood* words showed effects of base frequency at short time delays, but these did not persist at all time delays.

In Experiment 3, recall that *-ed* words induce effects of base frequency across the three shortest response delays (significant effects at 150 and 500 ms).

8.1.2 Speeded Naming

First, we found very similar effects of frequency on monomorphemic words, indicating that this task, like Speeded Lexical Decision is sensitive to differences in lexical frequency. For *–ity* words, we again found surface frequency effects when participants were responding quickly: this lack of base frequency effects for *–ity* is nicely consistent with all previous evidence. For *–able* words, where we found effects of both base and surface frequency in lexical decision even at the shortest response delays, we found only base frequency effects in speeded naming, also at solely short response delays.

-ness words presented a somewhat different pattern in Speeded Naming than in Speeded Lexical Decision. They showed surface frequency effects in both tasks, but in naming, the effect appeared only at short response delays, and in lexical decision it was also present at longer delays (an error effect). Also, the early base frequency effect found on error rates in lexical decision did not appear in naming.

Two tables summarizing these results are included below.

		150	**300**	**500**	**700**
Lex Dec RT	**surf freq effect**	-able	-ity -less		
	base freq effect	-able -hood	-able -less -ship	-ship	-able
Lex Dec Error Rates	**surf freq effect**	-ness	-less	-ness	-less
	base freq effect	-less -ed	-less -ness -ed	-less -ed	-less -ed
Naming RT	**surf freq effect**	-ity -ness	-ity	-ity	
	base freq effect	-able	-able		

Table 5. Summary of Frequency Effects Found In Experiments 1-4, arranged by effect.

	-ity	-ness	-less	-hood	-ship	-able	-ed
Lex Dec RT	early surface frequency effect		early surface frequency effect early base frequency effect	▨ early base frequency effect	▨ early-mid base frequency effect	early surface frequency effect base frequency effect throughout	
Lex Dec Error Rates		early-mid surface frequency effect early base frequency effect	surface frequency effect throughout base frequency effect throughout	▨	▨		early-mid base frequency effect
Naming RT	early-mid surface frequency effect	early surface frequency effect	▨	▨	▨	early base frequency effect	▨

Table 6. Summary of Frequency Effects Found In Experiments 1-4, arranged by suffix.

8.2 These Results in the Context of the Existing Models

8.2.1 The MRM Model.

Derived Words. If whole-word and decompositional access are proceeding in parallel for derived words, as the MRM holds, we would not expect base frequency effects to show up at very fast speeds; decomposed access representations could not be used to make lexical decisions at the access level, since information about the combinability of morphemes would not be available then, according to this model. However, base frequency effects across the different derivationally suffixed words in Experiments 1, 2, and 4 did appear when people responded quickly, which does not support the predictions of the MRM.

Inflected Words. In the context of the MRM, it makes sense that inflected words will be very sensitive to base frequency. Specifically, the MRM suggests that inflected words are accessed solely via decomposed access representations. Such an explanation is consistent with the presence of base frequency effects and complete lack of surface frequency effects found for -ed words in Experiment 3.

8.2.2 The AAM Model

Derived Words. If the lexical decisions were being made based on default whole-word access representations that are also sensitive to base frequency, as the AAM suggests, we would expect base and surface frequency effects even when lexical decisions are made quickly, and the pattern of results found for derived words in Experiments 1, 2, and 4 are consistent with such an account. However, if this type of access representation is indeed being used, we might expect these frequency effects to persist no matter the speed of the response. In almost all cases where base or surface frequency effects did appear, it was at shorter response delay rather than longer ones (few effects were present when participants responded at 700 ms).

Inflected Words. Since the AAM hinges on the use of whole-word access representations by default for known words, this model predicts that surface frequency effects should have appeared along with the base frequency effects we found for *-ed* words. Also, this model predicts that the effects would be consistent across response delays, which they were not.

So while the preceding data from Experiments 1 and 2 on derived words seemed better accounted for by the AAM, the MRM seems to make better predictions for inflected words. In addition, neither model can account for the differential effects that base and surface frequency had on response times vs. error rates. While some sets of suffixed words showed frequency effects on response times only, others showed them on error rates only, and *-less* words showed effects on both. And even more importantly, neither of these models takes into account the influences of base and surface frequency as they change over the timecourse of processing complex words.

8.3 The Dual-Route Decay Model

A model that has an architecture that is a hybrid of the MRM and AAM models, that also takes into account the timecourse of processing should be able to account for the relevant data more effectively. Here I propose the Dual-Route Decay Model, which makes use of the AAM's architecture for processing derived words and borrows from the MRM's architecture for inflected words. So for known derived words, whole-word access representations are used by default, and these are in many cases sensitive to base frequency due to long-term feedback from higher levels of processing, modulated by certain properties of suffixes (more about this part of the model when we discuss the data below). For inflected words, in contrast, only morpheme-by morpheme access representations are used, because of the distributional properties of inflections, appearing so frequently with a large number of different bases (note that the system does not have to take into account any qualitative difference between inflections and derivations). At the level of lexical entries, these representations are also fully specified for morphological structure, but frequency effects arise at the access level. See Figure 30 for a diagram of the model.

In terms of the timecourse of processing, I propose in the context of this model that frequency effects arise at the earliest stage of accessing a word. As mentioned in Chapter 2, for our purposes we will assume a search model: so when the incoming letter string is matched up with orthographic access representations, the latency is affected by frequency. Then, these effects decay with time. Specifically, if a reader makes a lexical decision or naming response early in processing, frequency effects should be highly apparent, because most lexical decisions or naming responses that participants make quickly are based on access representations. This depends on the notion that we are able, at least to some extent, interrupt processing through use of a speeded task. The effects of frequency may be strong enough to affect responses later in processing as well, but they eventually decay by the time responses are being made long after the level of access representations (e.g. by 700ms in the context of the present series of experiments).

Other linguistic factors may influence how long in the timecourse of processing a given frequency effect will persist. For example, those properties of a suffix that make it likely that words with a given suffix will show a base frequency effect may also make this base frequency effect apparent even after some time delay (again, this property of the model will be discussed further, in reference to specific data below).

8.3.1 Speeded Lexical Decision

Derived Words- Response Time Data. For derivations, the DDM makes the right predictions for many of our sets of results in Speeded Lexical Decision. In all but one

case of the response time results across Experiments 1 and 2, the frequency effects that do appear are no longer present by the 700ms delay condition.

Consistent with previous results, *-ity* words showed surface frequency effects, but not base frequency. The AAM had difficulty accounting for this systematic lack of decomposition effects because of its use of the feedback explanation for base frequency effects. Specifically, base-frequency effects result from long-term (over the course of all the reader's experiences) feedback, from a frequent base word, via the higher lexical level, to the suffixed access representation (recall Figure 1). For the DDM, it makes sense to add that this feedback is modulated by the linguistic properties of the suffix that the access representation contains. For example, we find no base frequency effects for *-ity* words: since they contain a phonologically non-neutral suffix, they are less affected by feedback from the base. In lexical decision response times, we find no frequency effects for -ness words. Some effects of frequency do appear in error rates, however, and these are discussed below.

The one set of lexical decision response time results where a frequency effect appears at 700ms is the base frequency effect for *-able* words. As part of the DDM, I suggest that base frequency has a particularly strong effect on the access representations of *-able* words, again due to the linguistic properties of the suffix.

Since the *-able* words have properties that make them particularly decomposable, they are highly affected by feedback from the base form, and because of the magnitude of this effect, is still present when participants respond after a longer delay: it does not decay as quickly. *-able* is a phonologically neutral suffix, and in previous studies such as Vannest and Boland (1999), that seemed to be the most important factor for whether or not a given suffix showed decomposition effects (also, shared form with a freestanding word seemed to magnify base frequency effects in Vannest et al, submitted). However, the other suffixes of this type that we have examined in the present experiments did not show such long-lasting frequency effect on response times. It is possible, then, that other factors hypothesized to support decompositional processing may be having an effect here such as productivity or semantic transparency. *-able* is a more frequent suffix than the other neutral suffixes we have examined (-ity, the non-neutral suffix is more frequent), both in types and tokens, which may indicate its productivity, and it is also one of the more productive suffixes when calculated by the method of Baayen and others.[11]

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[11] The percentage of words with that syntactic category that have a given suffix and only appear once: i.e. what percentage of the adjectives in the database are -able words that only appear once?

Semantic transparency ratings are not available for *-able* either, but intuitively it seem to be more clear and consistent in meaning. Perhaps these factors make the base frequency effect especially strong and help it at longer response delays.

Derived Words - Error Data. For *-ness* words in Experiment 1, we found both base and surface frequency effect on error rates that were absent by the 700 ms delay, consistent with the DDM. The surface frequency effect was more robust and persistent than the base frequency effect, which was significant only at the 300ms delay. It is not obvious why the effects for *-ness* words resulted on error rates and not on response times, but apparently participants set a response criterion for their responses that was often too early to make accurate responses to low-frequency *-ness* words. Frequency levels were relatively similar across the sets of suffixed words, but for the *-ness* words, participants made errors instead of making slower, but still correct, response.

Even more difficult to explain are the patterns of error rates for *-less* words in Experiment 2, where in response times, we found early base and surface frequency effects, consistent with the DDM. In terms of the error rates, both of these effects are present across response delays. *-less* words are the only set where we found both response time and error effects. Perhaps individual differences in participants' strategies results in some responding to low-frequency words more slowly, and some simply making errors (though we might expect this, then, in other experiments). Further analyses of the data may shed some light on this question.

Inflected Words. For *-ed* inflected words in Experiment 3, the only effects found were base frequency effects on error rates at the short-mid response delays. Since inflected words are accessed solely via morpheme-by-morpheme representations in the DDM, these results are quite consistent. At the level of access representations, the model predicts only base frequency effects for these words, then these effects decay and are not present at the 700 ms delay. The DDM predicts that this pattern would hold for all inflections, at least those with the distributional pattern of appearing so frequently with so many different bases, like *-ed*.

8.3.2 Speeded Naming

Derived Words -Response Time Data. The results in Speeded Naming were to some degree consistent with the data for the same derived words in Speeded Lexical Decision. Both *-ity* and *-ness* words showed surface frequency effects that were attenuated by the longest response delays, consistent with the DDM, and for *-able* words, we found a base frequency effect that showed the same type of decay pattern.

However, the base frequency effect we found for *-ness* words and the surface frequency effect for *-able* words we found in Speeded Lexical Decision were absent in Speeded Naming. This does not fall directly from the predictions of the DDM or any other model we have discussed, since we predict access representations to be immediately sensitive to frequency. However, as Grainger (1990), Kello and Plaut (2000) and others explain, frequency effects can sometimes be reduced in magnitude in naming versus lexical decision, because of some reliance on sublexical processes of spelling-to-sound conversion, which are by definition not sensitive to lexical frequency

for regularly spelled words. Most of the suffixed words in these experiments had fairly regular spellings, but this does not account for the selective attenuation of the base frequency effect for *-ness* words and the surface frequency effect for *-able* words. Neither of these effects was particularly robust in Speeded Lexical Decision, so perhaps the difference between lexical decision and naming helps to account for their absence. Also, speculatively, it is possible that spoken word frequency, rather than written frequency may influence naming and not visual lexical decision, and the frequency contrasts set up in the experiments may not have been adequate according to such criteria.

Again, the DDM does a reasonable job of predicting many of the effects found in Speeded Lexical Decision and Speeded Naming, since in so many cases, frequency effects appear when response delays are short, but not when they are longer. In addition, this model accounts for the systematic presence and absence of base frequency effects by allowing linguistic properties of a suffixed form to modulate how it is affected by long-term feedback from the base form via the higher lexical level. This model makes a strong claim about the timecourse of morphological processing that fits with a great deal of the existing data but clearly needs further testing.

8.4 Possibilities for Future Work

In future work, I plan to further test the predictions of the Dual-Route Decay Model through further Speeded Lexical Decision Experiments. Because lexical decision seems to be the task most sensitive to differences in lexical frequency even when response times are made under time pressure, it seems to be the optimal task to pursue in future experiments, rather than naming.

Of particular interest is the DDM's prediction of immediate sensitivity of lexical representations to frequency. In future experiments, it would make sense to examine response delays even shorter than 150 ms: in the present data, accuracy levels were well over chance for all sets of even low-frequency words at this short delay, so we would expect reasonable accuracy levels, and frequency effects when responses are made more quickly. Also, these faster responses, where error rates would likely be higher, may have to clarify the discrepancy between error effects and response time effects that we found for derived words.

Another possibility for investigating responses made early in the processing of suffixed words would be to decrease the duration of the visual presentation of the words. In all the experiments presented above, the word was presented until the participant made a response. Experimenter control over the presentation duration in combination with use

of a response cue would give further insight into responses made very quickly, and also might induce effects on error rates, that, similar to the speed-accuracy tradeoff found above, could interact with frequency effects.

Furthermore, this model should be tested with speeded experiments on words with a wider range of inflectional and derivational affixes. Specifically, further tests of the differences between the processing of derived versus inflected words would be appropriate.

Even based on the present series of experiments, however, the Dual-Route Decay model offers a better-constrained version of a Dual-Route model of morphological processing. This model makes specific predictions about the timecourse of processing derived and inflected words, and data from Speeded Lexical Decision and Speeded Naming confirm these predictions to a large extent. Further work will help to refine such a model even more in order to give an accurate picture of how morphological processing takes place in real time.

BIBLIOGRAPHY

Alegre, M. & Gordon, P. 1999b. "Frequency Effects and the Representational Status of Regular Inflections." Journal of Memory and Language 40, 41-61.

Alegre, M. & Gordon, P. 1999b. "Rule-based versus Associative Processes in Derivational Morphology." Brain and Language 68, 347-354.

Baayen, R. H., Dijkstra, T., and Schreuder, R. 1997. "Singulars and Plurals in Dutch: Evidence for a parallel dual-route model". Journal of Memory and Language 37, 94-117.

Baayen, R. H., and Schreuder, R. 1996. "Modelling the processing of morphologically complex words". In Dijkstra, T. and de Smedt, K., et al (Eds); Computational psycholinguistics: AI and connectionist models of human language processing. London: Taylor and Francis.

Badecker, W. and Caramazza, A. 1991. "Morphological Composition in the Lexical Output System". Cognitive Neuropsychology 8(5) 335-367.

Bertram, R., Hyona J., & Laine, M. (submitted). "Morphology in Context: Effects of Base and Surface Frequency".

Bertram, R., Laine, M and Karvinen, K. 1999. "The interplay of word formation type, affixal homonymy, and productivity in lexical processing: Evidence from a morphologically rich language." Journal of Psycholinguistic Research 28(3), 213 226.

Bertram, R., Schreuder, R., and Baayen, R. H. 2000. "The balance of storage and computation in morphological processing: the role of Word Formation Type, Affixal Homonymy, and Productivity." Journal of Experimental Psychology: Learning, Memory, and Cognition, 26(2), 1-23.

Bradley, D. 1979. "Lexical representation of derivational relation". In M. Aronoff and M. Kean (Eds.), Juncture. Saratoga, CA: Anna Libri.

Butterworth, B. 1983. "Lexical Representation". In B. Butterworth (Ed.) Language Production: Vol. 2. London: Academic Press.

Caramazza, A., Laudanna, A. and. & Romani, C. 1988. "Lexical Access and inflectional morphology." Cognition 28, 297-332.

Cole, P., Segui, J., and Taft, M. 1997. "Words and morphemes as units for lexical access". Journal of Memory and Language 37, 312-330.

Forster, K. 1976. "Accessing the mental lexicon." In R. Wales and E. Walker, (Eds) New Approaches to Language Mechanisms. Amsterdam, North Holland.

Grainger, J. 1990. "Word frequency and neighborhood frequency effects in lexical decision and naming." Journal of Memory & Language 29, 228-244.

Hankamer, J. 1989. "Morphological parsing and the lexicon." In W. Marslen-Wilson, (Ed.); Lexical representation and process. Cambridge, MA: MIT Press.

Herdman, C. 1992. "Attentional resource demands of visual word recognition in naming and lexical decisions". Journal of Experimental Psychology: Human Perception & Performance 18(2) 460-470.

Hyona, J. Laine, M. and Niemi, J. 1995. "Effects of a word's morphological complexity on readers' eye fixation patterns". Eye movement research: Mechanisms, processes and applications, 445-452. Amsterdam: Elsevier.

Ito,T., Sugioka, Y. and Hagiwara, T. 1996. "Psychological Status of Rules in Derivational Morphology: Evidence from Japanese Nominal Suffixation". Metropolitan Linguistics 16, 18-30.

Jared, D. 1997. "Evidence that strategy effects in word naming reflect changes in output timing rather than changes in processing route". Journal of Experimental Psychology: Learning, Memory, & Cognition 23(6), 1424-1438.

Johnson, N., Childers, T., Miller, B. and Replogle, V. 2001. "What is the effect of cohort or neighborhood size on lexical processing?" Unpublished Manuscript, The OhioState University.

Kello, and Plaut, D. 2000. "Strategic control in word reading: Evidence from speeded responding in the tempo-naming task". Journal of Experimental Psychology: Learning, Memory, and Cognition 26(3), 719-750.

Lukatela, G.; Gligorijevic, B.; Kostic, A.; Turvey, M. T. 1980. "Representation of inflected nouns in the internal lexicon." Memory & Cognition 8(5), 415-423

Marslen-Wilson, W., Tyler, L., Waksler, R., and Older, L. 1994. "Morphology and meaning in the mental lexicon." Psychological Review 101 (1) 3-33.

Marslen-Wilson, W. and Zhou X. 1999. "Abstractness, Allomorphy, and Lexical Architecture". Language and Cognitive Processes 14 (4) 321-352.

Meyer, D. Irwin, D.; Osman, A.; Kounios, J. 1988. "The dynamics of cognition and action: Mental processes inferred from speed-accuracy decomposition." Psychological Review 95, 183-237.

McElree, B. 1996. "Accessing short-term memory with semantic and phonological information: A time-course analysis." Memory & Cognition 24(2), 173-187.

McQueen, J. and Cutler, A. 1998. "Morphology in Word Recognition". In Zwicky, A. Spencer, A. (Eds). The Handbook of Morphology. Oxford: Blackwell.

Morrison, C., and Ellis, A. (2000) "Real age of acquisition effects in word naming and lexical decision". British Journal of Psychology 91(2), 167-180.

Niemi,J., Laine, M., and Tuominen, J. 1994. "Cognitive Morphology in Finnish: Foundations of a new model". Language and Cognitive Processes 9(3), 423-446.

Raveh, M., and Rueckl, J. " Equivalent effects of inflected and derived primes: Long term morphological priming in fragment completion and lexical decision". Journal of Memory & Language Vol 42(1)2000 p.103-119

Rueckl, J., Mikolinski, M., Raveh, M., Miner, C. and Mars, F. 1997. "Morphological priming, fragment completion, and connectionist networks." Journal of Memory & Language Vol 36(3), 382-405.

Schreuder, R. and Baayen, R. H. 1995. Modeling morphological processing. In Feldman, L. (Ed). Morphological aspects of language processing. Lawrence Erlbaum Associates, Inc.:Hillsdale, NJ. 131-154.

Schilling, H.; Rayner, K. & Chumbley, J. (1998) "Comparing naming, lexical decision, and eye fixation times: Word frequency effects and individual differences." Memory & Cognition 26. 1270-1281.

Taft, M. & Forster, K. 1975. "Lexical storage and retrieval of prefixed words". Journal of Verbal Learning and Verbal Behavior 14, 638-647.

Taft, M. 1979. "Recognition of affixed words and the word frequency effect." Memory & Cognition Vol 7(4), 263-272

Tyler, L. Marslen-Wilson, W. Rentoul, J. and Hanney, P. 1988. "Continuous and Discontinuous Access in Spoken Word Recognition: the role of derivational prefixes". Journal of Memory and Language 27, 368-381.

Vannest, J. and Boland, J. 1999. "Lexical Morphology and lexical access." Brain and Language 68, 324-332.

Vannest, J., Bertram, R. Jarvikivi, J. and Niemi, J. (submitted)."Counterintuitive Cross Linguistic Differences: More Morphological Computation in English than in Finnish."

Wurm, L. 1997. "Auditory processing of prefixed English words is both continuous and decompositional". unpublished manuscript. SUNY Stony Brook.

APPENDIX A

SCRIPT FOR SEARCHING THE MRC DATABASE TO TABULATE BASE FREQUENCY

```
#!/usr/bin/perl

#this perl script finds all words in the MRC database which have some suffix,
#and for each word trys to find all instances of words
#having the same root as the suffixed word.  It reports the summed KF
#frequency of the forms having that root (as well as the suffixed form).

open(MRC,'/n/julius/0/kjohnson/mrc/mrc.txt') or die "can't open mrc.txt: $!\n";

print "Search the MRC database for relative frequencies of suffixed and root fo\
rms\n";
print " The quick way to say \"no\" to a yes\/no question is to press return\n"\
;
print "\nEnter the suffix that you are interested in: ";
chomp($suffix = <STDIN>);

print "\nWe now ask for an output filename.  If you enter the name of \n";
print "an existing file the program will try to skip affixed words that \n";
print "you have already looked at.\n\n";
print "Enter a name for the output file: ";
chomp($outname = <STDIN>);

# check to see if this file exists.  if so store the words
if (-e $outname) {
   print "\tfile $outname exits and is being checked\n";
   open(OUTPUT,"$outname");
   while ($line = <OUTPUT>) {
      ($word,$remainder) = split(' ',$line);
      $oldwords{$word} = 1;
   }
   close(OUTPUT);
}

#now open the output file to append the new information
open(OUTPUT, ">>$outname");

while ($line = <MRC>) {

   ($freq,$TLfreq,$brown,$PS,$word,$stress) = split(' ',$line);
```

```
   if (($word =~ /$suffix$/i) && (!$oldwords{$word})){
      $words{$word} = "$freq";
   }
}

#we now have a hash table %words which contains keys $word and values $freq

#header line for output file
print OUTPUT "word\$ freq stem\$ sfreq n\n";

foreach $word (sort keys %words) {
   print "\nlook for forms related to \"$word\" (y or n: q to quit)? ";
   $ans = <STDIN>;
   if ($ans =~ /^q/i) { last; } #'q' = stop looking at words.
   if ($ans !~ /^y/i) { next; } #'y' = skip to next word in list

   $freq = $words{$word};
   printf OUTPUT "%s %d ", $word, $freq; #save whole-word info

   ($stem=$word) =~ s/$suffix$//i; #remove suffix

   print "$word: Using the stem: \"$stem\"\n";
   print "Chop off the last character of the stem (y or n)? ";
   if (<STDIN> =~ /^y/i) {chop $stem;}

   $stemfreq = 0;
   $numforms = 0;
   $old_word = '';

   seek MRC,0,0; #go through the dictionary again

   while ($line = <MRC>) {

      ($freq,$TLfreq,$brown,$PS,$word2,$stress) = split(/\s+/,$line);

      if (($word2 =~ /$stem/i) && ($word2 ne $old_word)) {
         print "$word: use \"$word2\" (y/n)?";
         if (<STDIN> =~ /^y/i) {
            $stemfreq += $freq;
            $numforms++;
         }      }
      $old_word = "$word2";
   }
   printf OUTPUT "%s %d %d\n",$stem, $stemfreq, $numforms;
}
close MRC;
close OUTPUT;
```

APPENDIX B
CRITICAL ITEMS IN EXPERIMENTS 1 AND 4

condition	
able, hi base	VARIABLE
	AGREEABLE
	MOVEABLE
	PRESENTABLE
	CHANGEABLE
	DEPENDABLE
	QUESTIONABLE
	COUNTABLE
	IMAGINABLE
	PASSABLE
	LOVABLE
	READABLE
	DRIVEABLE
	FIXABLE
	RECOGNIZABLE
able, lo base	SUITABLE
	OBTAINABLE
	PROFITABLE
	ADAPTABLE
	COMMENDABLE
	PREDICTABLE
	DETECTABLE
	EXPENDABLE
	REGRETTABLE
	PUNISHABLE
	PERISHABLE
	DETACHABLE
	ENJOYABLE
	ENVIABLE
	DEPLORABLE
able, hi surf	COMFORTABLE
	CONSIDERABLE
	DESIRABLE
	NOTABLE
	VALUABLE
	VARIABLE
	SUITABLE
	ACCEPTABLE
	RESPECTABLE
	MOVABLE
	PROFITABLE
	AGREEABLE
	COMPARABLE
	NOTICEABLE
	OBTAINABLE

able, lo surf	APPROACHABLE
	PAYABLE
	ACCOUNTABLE
	CHANGEABLE
	NAMEABLE
	PRESENTABLE
	BEARABLE
	ANSWERABLE
	BELIEVABLE
	GOVERNABLE
	ATTACHABLE
	DRINKABLE
	BREAKABLE
	EXCITABLE
	MISTAKABLE
ness, hi base	BIGNESS
	BLACKNESS
	COOLNESS
	COLDNESS
	DRYNESS
	FIRMNESS
	OPENNESS
	ROUNDNESS
	FRESHNESS
	HEAVINESS
ness, lo base	BLANDNESS
	FONDNESS
	SICKNESS
	FALSENESS
	GRIMNESS
	IDLENESS
	CUTENESS
	DAMPNESS
	BALDNESS
	MILDNESS
ness, hi surf	DARKNESS
	THICKNESS
	WEAKNESS
	BITTERNESS
	AWARENESS
	ILLNESS
	BRIGHTNESS
	HAPPINESS
	GOODNESS
	READINESS

ness, lo surf	BLACKNESS
	BARENESS
	FLATNESS
	NICENESS
	POORNESS
	NEARNESS
	PRETTINESS
	QUICKNESS
	ROUNDNESS
	WIDENESS
ity, hi base	GENERALITY
	TOTALITY
	HUMANITY
	LIBERALITY
	FINALITY
	CIVILITY
	COMPLEXITY
	MODERNITY
	EQUALITY
	RAPIDITY
ity, lo base	AGILITY
	IMMENSITY
	DENSITY
	DEFORMITY
	SEVERITY
	ACIDITY
	BRUTALITY
	OBESITY
	HUMIDITY
	PLURALITY
ity, hi surf	AUTHORITY
	POSSIBILITY
	REALITY
	SECURITY
	MAJORITY
	DENSITY
	MORALITY
	ABILITY
	MATURITY
	INTENSITY
ity, lo surf	RELATIVITY
	LOCALITY
	MODERNITY
	PROFUNDITY
	TOTALITY
	MENTALITY
	HOSPITALITY
	CENTRALITY
	ANIMALITY
	COMPLEXITY

monomorphemic, low	SYRINGE
	SILICON
	SHAMPOO
	SCHNAPPS
	SABOTAGE
	REMNANT
	RAMPANT
	RACQUET
	PARSLEY
	PAMPHLET
	NOSTRIL
	MORPHINE
	MINSTREL
	MACKEREL
	LOBSTER
	LEPROSY
	LARCENY
	GENTEEL
	FLOURIDE
	CROCODILE
monomorphemic, high	WEATHER
	TROUBLE
	TRAFFIC
	THOUGHT
	SUCCESS
	STRUGGLE
	STRENGTH
	STRAIGHT
	PERFECT
	PROMISE
	KITCHEN
	EXTREME
	ELEMENT
	HUSBAND
	CORRECT
	COLLEGE
	BRILLIANT
	BILLION
	BENEATH
	ANSWER

APPENDIX C
CRITICAL ITEMS IN EXPERIMENT 2

-less, hi base	GODLESS
	NAMELESS
	VIEWLESS
	PAINLESS
	SPOTLESS
	HOPELESS
	THOUGHTLESS
	WORTHLESS
-less, lo base	HEEDLESS
	PITILESS
	REMORSELESS
	PENNILESS
	DAUNTLESS
	COUNTLESS
	STAINLESS
	SEAMLESS
-less, hi surf	REGARDLESS
	HELPLESS
	ENDLESS
	USELESS
	MEANINGLESS
	DOUBTLESS
	HOPELESS
	COUNTLESS
-less, lo surf	POINTLESS
	PLACELESS
	HAIRLESS
	VOICELESS
	TASTELESS
	PURPOSELESS
	WORTHLESS
	GODLESS

-ship, hi base	TOWNSHIP
	EDITORSHIP
	STUDENTSHIP
	FRIENDSHIP
	LORDSHIP
	COURTSHIP
	JUDGESHIP
	HARDSHIP
	FELLOWSHIP
	ATTORNEYSHIP
-ship, lo base	AUTHORSHIP
	COMRADESHIP
	PARTNERSHIP
	KINSHIP
	CITIZENSHIP
	OWNERSHIP
	CHAMPIONSHIP
	SCHOLARSHIP
	TRUSTEESHIP
	APPRENTICESHIP
-hood, hi base	MOTHERHOOD
	BOYHOOD
	FATHERHOOD
	GIRLHOOD
	KINGHOOD
	MANHOOD
	WOMANHOOD
	PERSONHOOD
	LADYHOOD
	BROTHERHOOD
-hood, lo base	SAINTHOOD
	BACHELORHOOD
	INFANTHOOD
	KNIGHTHOOD
	MAIDENHOOD
	PRIESTHOOD
	SISTERHOOD
	ADULTHOOD
	WIDOWHOOD
	FALSEHOOD

APPENDIX D
CRITICAL ITEMS IN EXPERIMENT 3

-ed, hi base	ATTEMPTED
	DRESSED
	BALANCED
	ATTACKED
	MARCHED
	ACCEPTED
	ASSISTED
	ANSWERED
	DIRECTED
	FOLLOWED
	BOTTLED
	PRICED
	COASTED
	GUARDED
	BONDED
-ed, low base	BLEACHED
	GOBBLED
	GROANED
	BLISTERED
	BLINKED
	HAUNTED
	GLEAMED
	GRUMBLED
	GROOMED
	ADDICTED
	ERASED
	LAPSED
	STIFLED
	BLAZED
	HURLED

-ed, hi surf	SLIPPED
	LOCKED
	WORRIED
	AFFECTED
	MOUNTED
	ADVANCED
	FINISHED
	TOUCHED
	PAINTED
	DROPPED
	COLLECTED
	PLEASED
	COVERED
	APPLIED
	VARIED
-ed, lo surf	LISTENED
	AVOIDED
	BATTLED
	BALANCED
	ATTACKED
	HANDLED
	MARCHED
	ACCEPTED
	ASSISTED
	ANSWERED
	MARKETED
	MOTHERED
	FIGURED
	MAJORED
	FOLLOWED

APPENDIX E
FIGURES

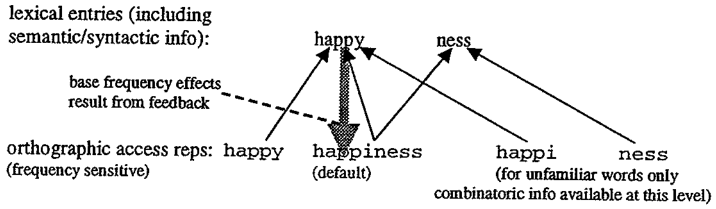

Figure 1. The AAM Model

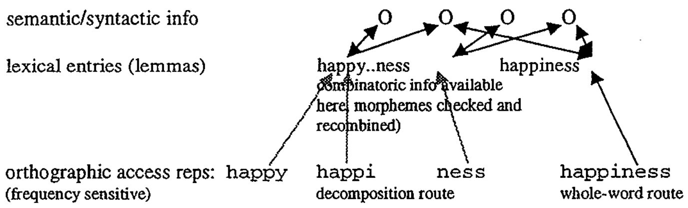

Figure 2. The MRM model.

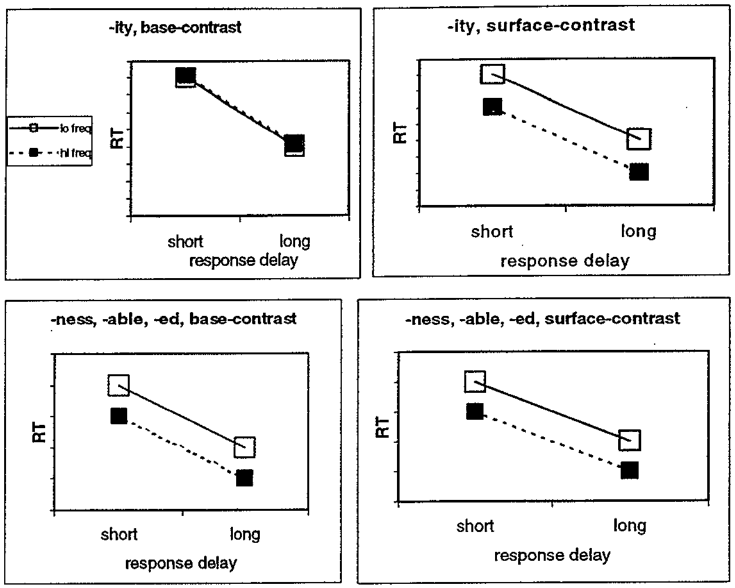

Figure 3. Predictions of the AAM Model

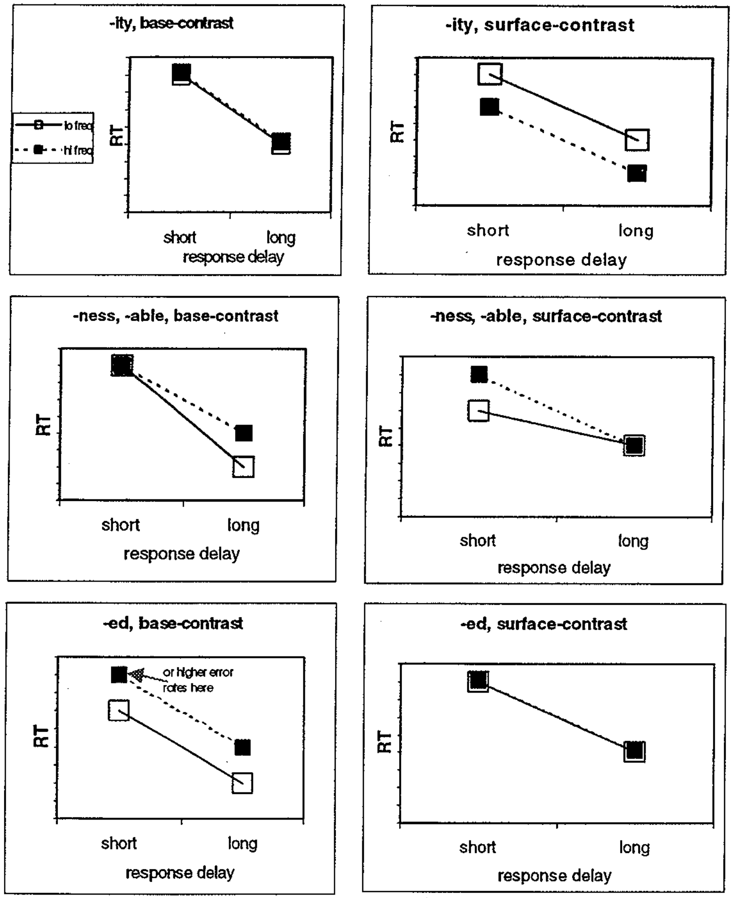

Figure 4. Predictions of the MRM Model.

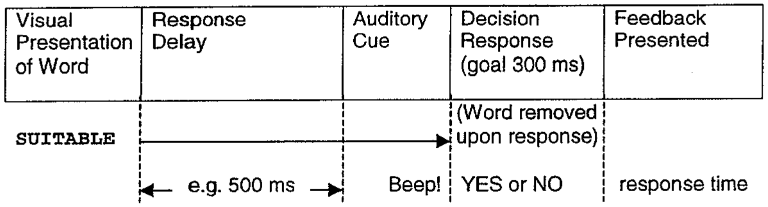

Figure 5. The Speeded Lexical Decision Task.

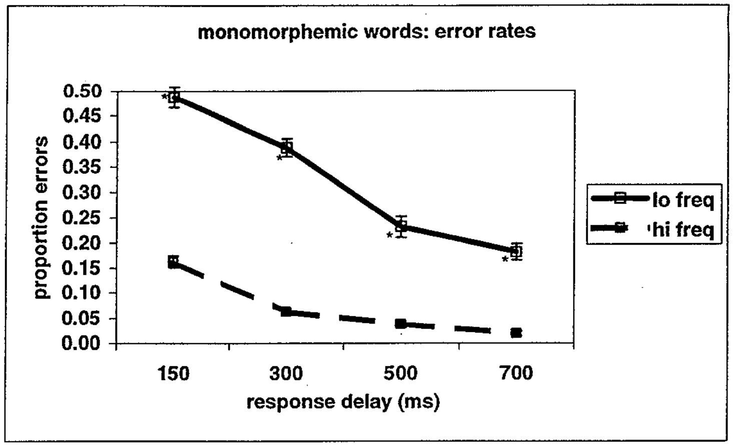

Figure 6. Error Rates on Monomorphemic Words in Experiment 1. Statistically significant effects are marked with a *.

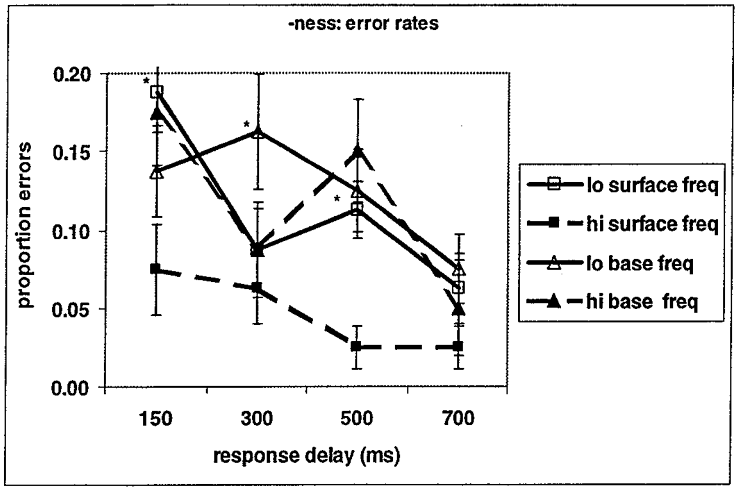

Figure 7. Error Rates on *–ness* Words in Experiment 1. Statistically significant effects are marked with a *.

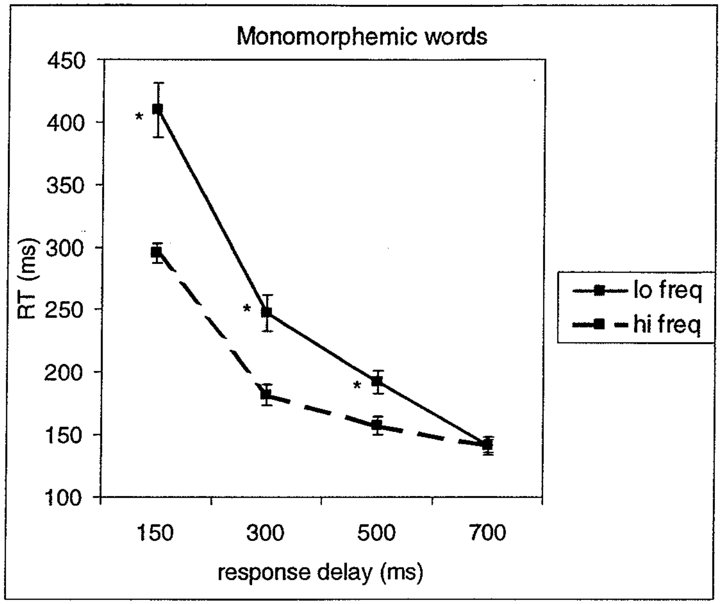

Figure 8. Response Times to Monomorphemic Words in Experiment 1. Statistically significant effects are marked with a *.

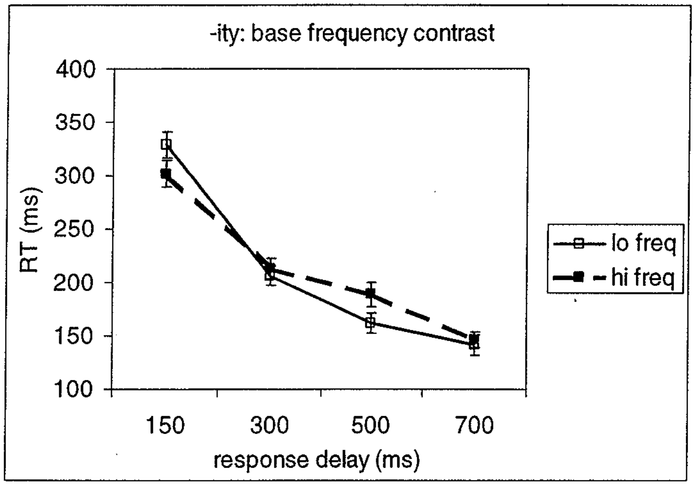

Figure 9. Response Times to Base-Contrast *–ity* words in Experiment 1.

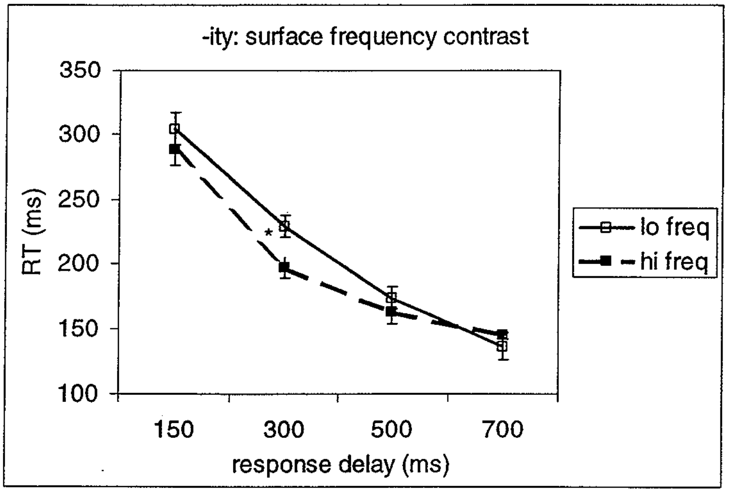

Figure 10. Response Times to Surface-Contrast *–ity* words in Experiment 1. Statistically significant effects are marked with a *.

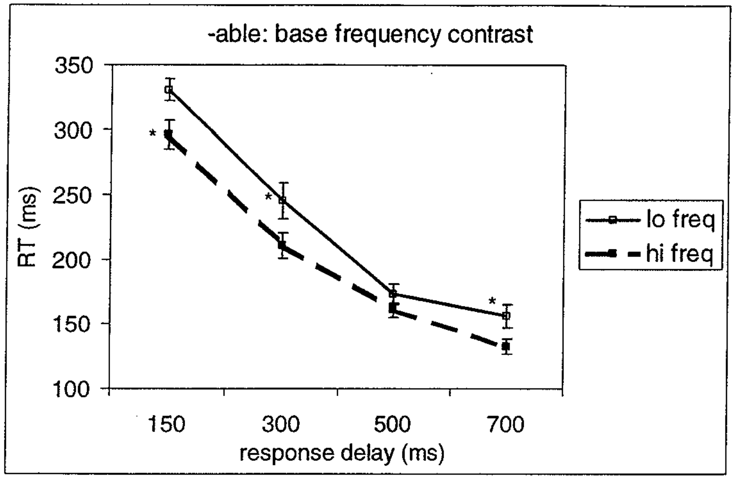

Figure 11. Response Times to Base-Contrast *–able* words in Experiment 1. Statistically significant effects are marked with a *.

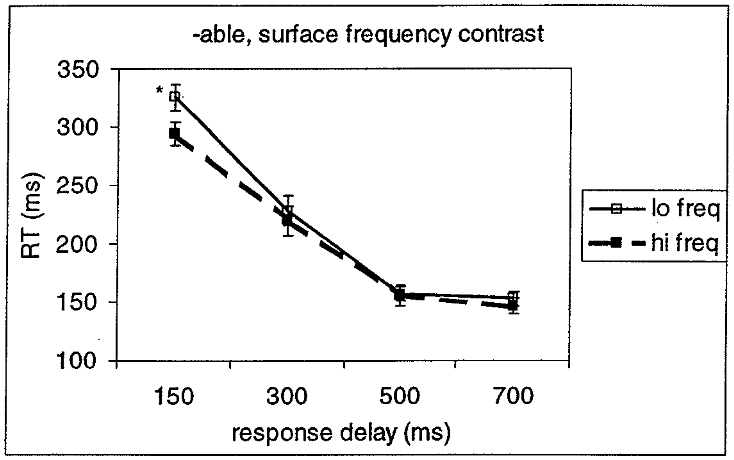

Figure 12. Response Times to Surface-Contrast *–able* words in Experiment 1. Statistically significant effects are marked with a *.

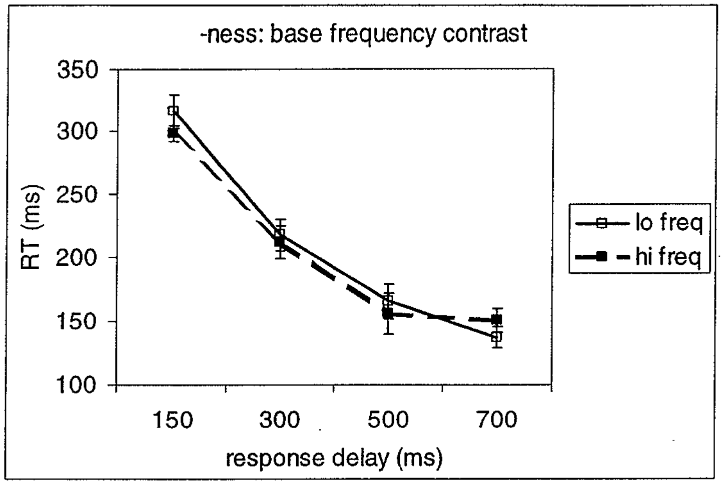

Figure 13. Response Times to Base-Contrast *–ness* words in Experiment 1.

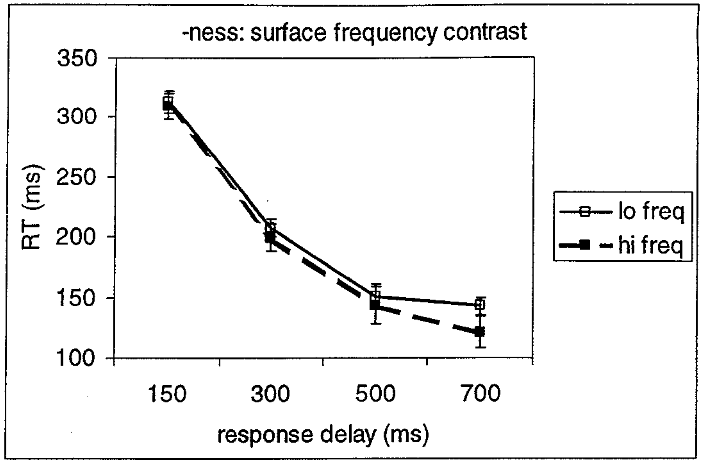

Figure 14. Response Times to Surface-Contrast *–ness* words in Experiment 1.

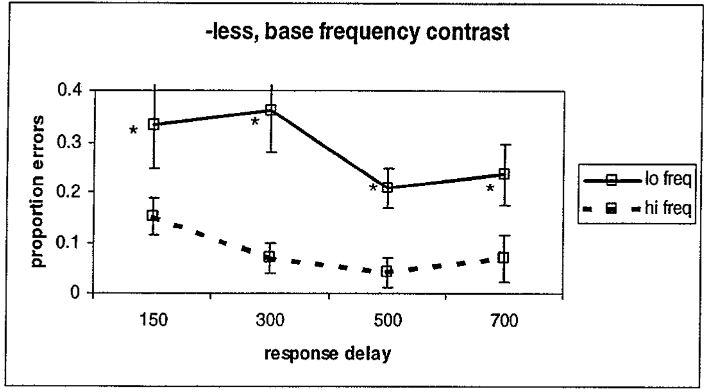

Figure 15. Error Rates on Base-Contrast *–less* words in Experiment 2. Statistically significant effects are marked with a *.

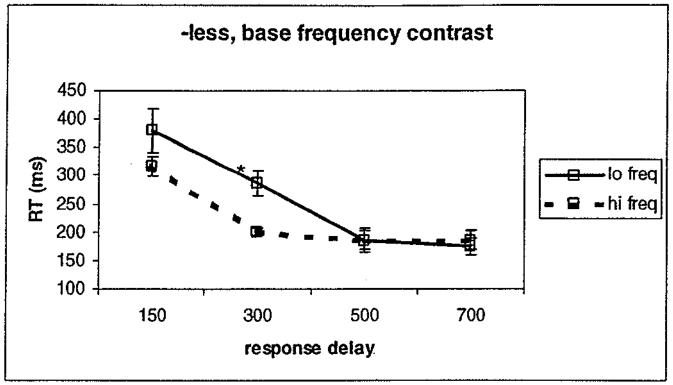

Figure 17. Response Times to Base-Contrast *–less* words in Experiment 2. Statistically significant effects are marked with a *.

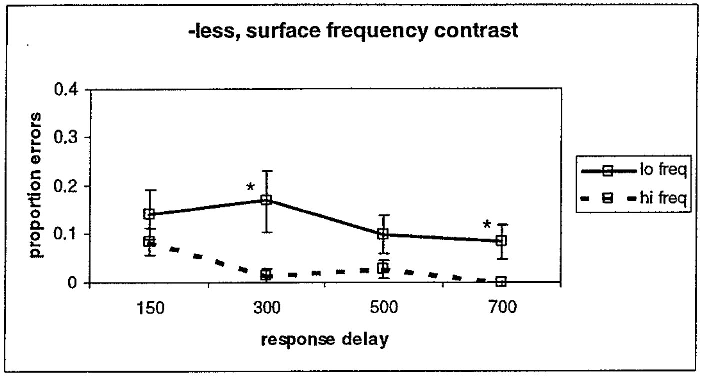

Figure 16. Error Rates on Surface-Contrast *–less* words in Experiment 2. Statistically significant effects are marked with a *.

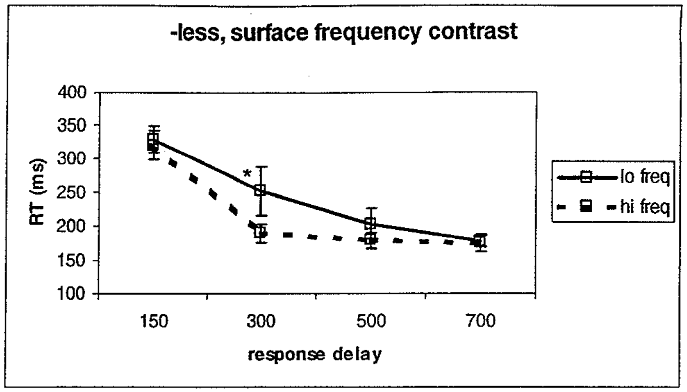

Figure 18. Response Times to Surface-Contrast *–less* words in Experiment 2. Statistically significant effects are marked with a *.

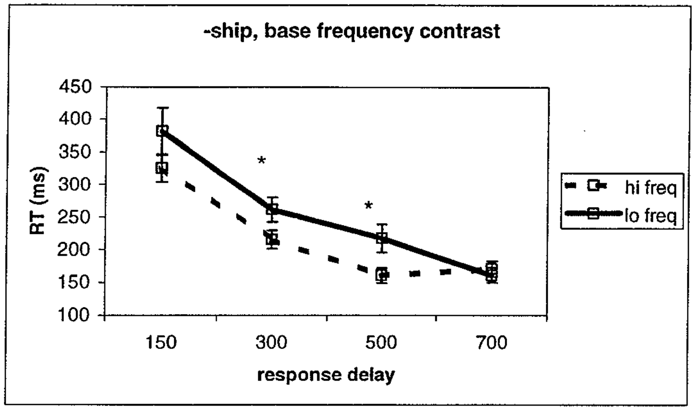

Figure 19. Response Times to Base-Contrast *–ship* words in Experiment 2. Statistically significant effects are marked with a *.

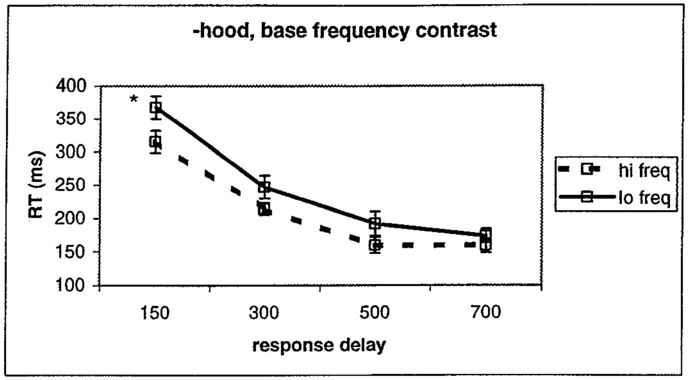

Figure 20. Response Times to Surface-Contrast *–hood* words in Experiment 2. Statistically significant effects are marked with a *.

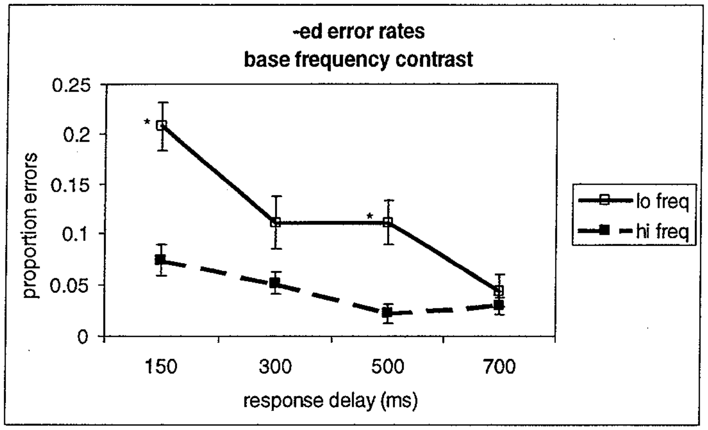

Figure 21. Error Rates on Base-Contrast *–ed* words in Experiment 3. Statistically significant effects are marked with a *.

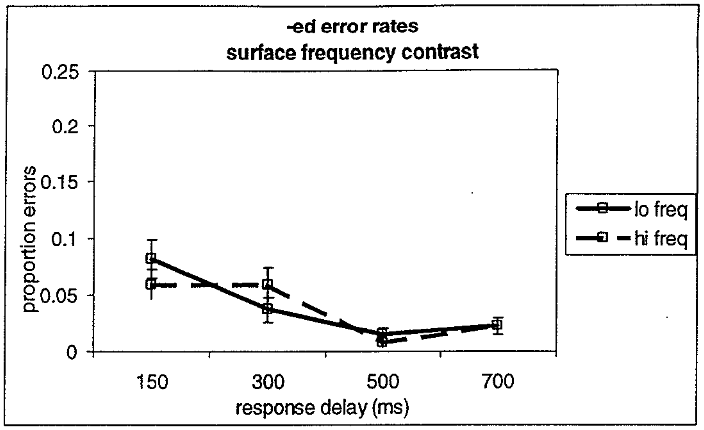

Figure 22. Error Rates on Surface-Contrast *–ed* words in Experiment 3.

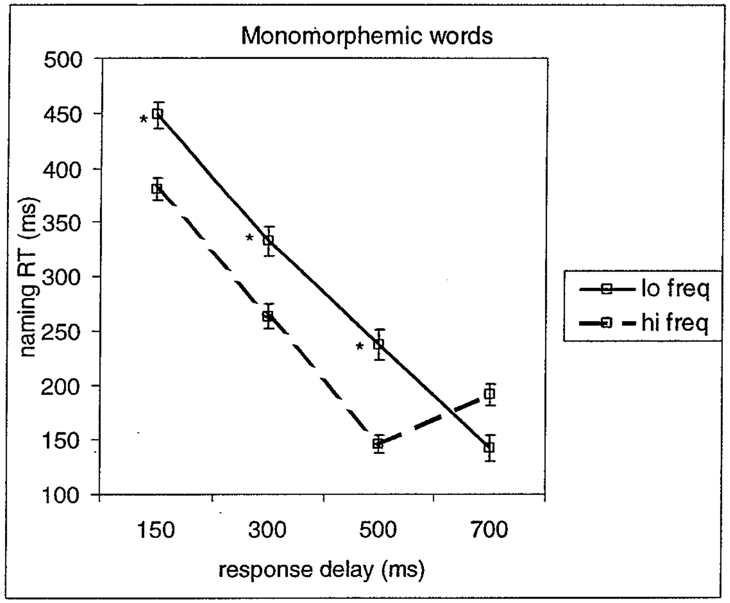

Figure 23. Naming Response Times to Monomorphemic Words in Experiment 4. Statistically significant effects are marked with a *.

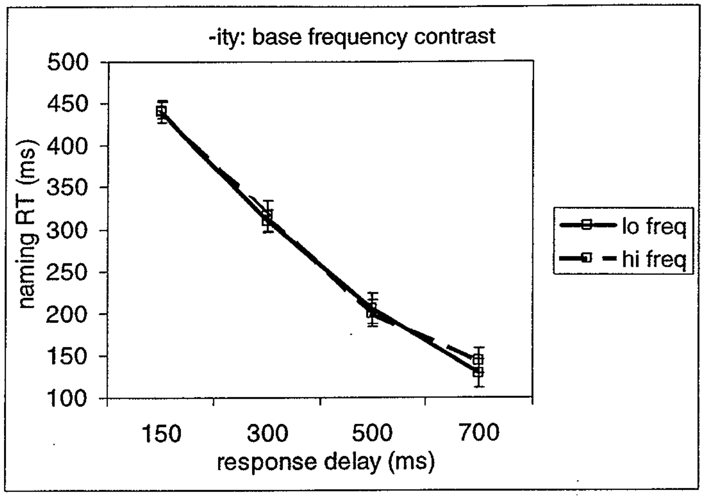

Figure 24. Naming Response Times to Base-Contrast *–ity* words in Experiment 4.

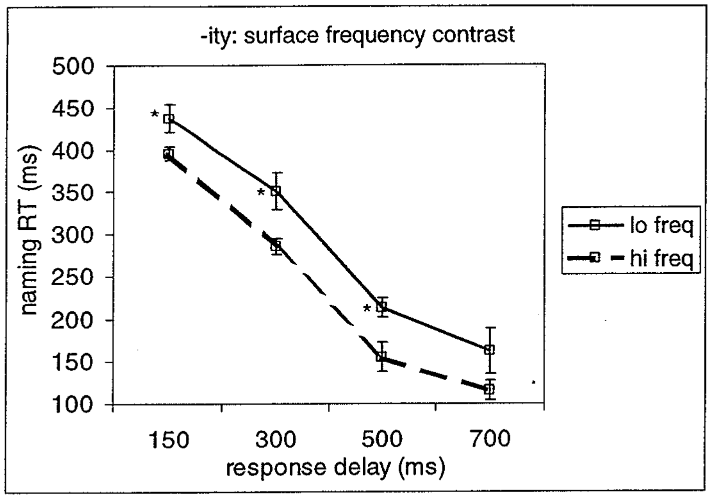

Figure 25. Naming Response Times to Surface-Contrast *–ity* words in Experiment 4. Statistically significant effects are marked with a *.

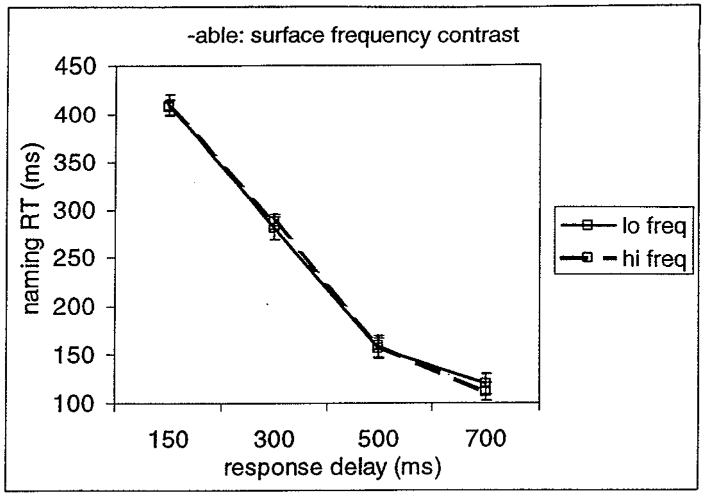

Figure 27. Naming Response Times to Surface-Contrast *–able* words in Experiment 4.

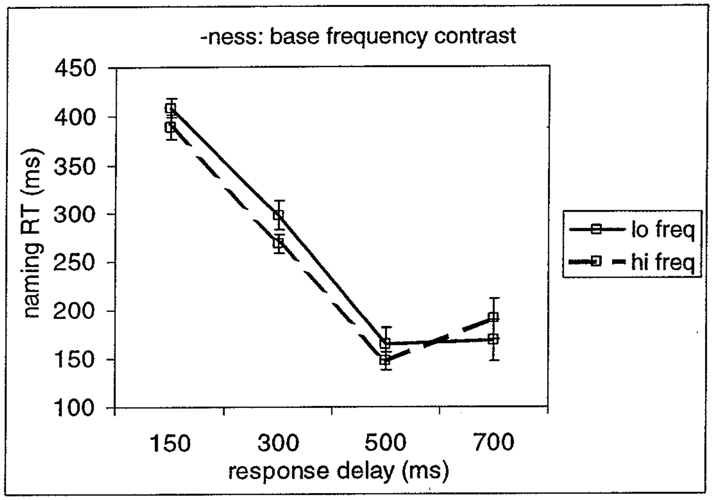

Figure 28. Naming Response Times to Base-Contrast *–ness* words in Experiment 4.

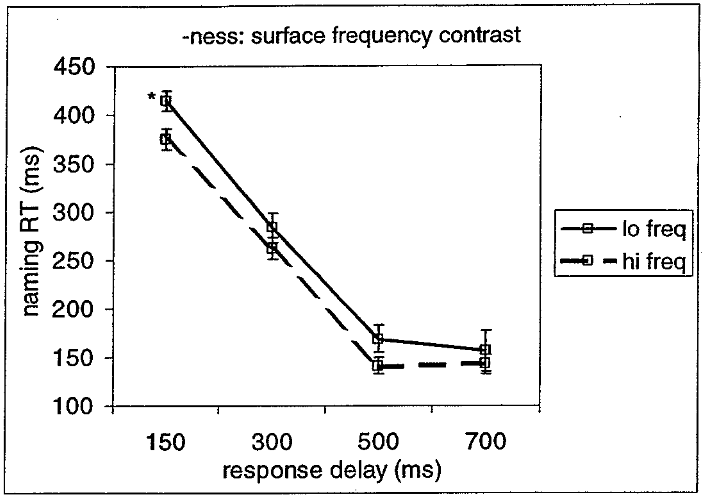

Figure 29. Naming Response Times to Surface-Contrast *–ness* words in Experiment 4. Statistically significant effects are marked with a *.

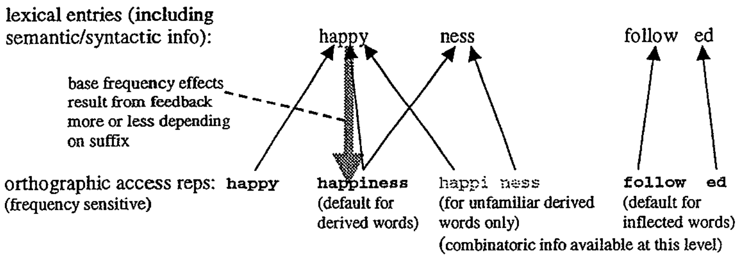

Figure 30. The Dual-Route Decay Model